SILICON CHIP

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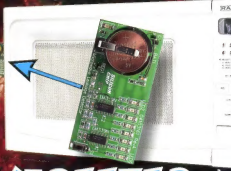

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SILICON CHIP MAGAZINE JULY 2013 KC-5522

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KC-5516

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SILICON CHIP MAGAZINE MAY 2013 KC-5521

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$39.95

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SILICON CHIP MAGAZINE AUGUST 2014 KC-5529

This electronic thermostat is ideal for converting a chest freezer into an energy-efficient fridge, converting a fridge into a wine cooler or controlling heaters in home-brew setups, hatcheries and fish tanks. It controls everything directly via its power cable, so there's no need to modify its internal wiring. It can even be adapted to control 12V or 24V fridges or freezers.

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Mains Timer Kit for Fans and Lights

SILICON CHIP MAGAZINE AUGUST 2012 KC-5512

This simple circuit provides a turn-off delay for a 230VAC light or a fan, such as a bathroom fan set to run for a short period after the switch has been tuned off. The circuit consumes no stand by power when load is off. Overall timing period is set by capacitor C1. Supplied with 100nF for a delay of 1, 5, 10 or 20 minutes set by one of 4 links.60 x 76mm PCB.

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SILICON CHIP MAGAZINE JANUARY 2009 KC-5473

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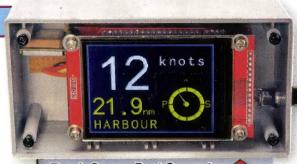

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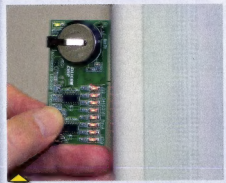

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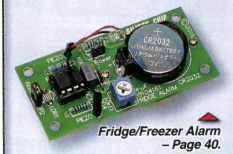

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Publisher's Letter

Arduino, Raspberry Pi or Maximite – which will gain the ascendancy?

As a politician would say, it is a very exciting time to be involved in electronics. As far as components are concerned we have the challenges associated with the rapid changeover from through-hole to surface mount devices. Their minuscule size certainly makes them a challenge for anyone without good close-up vision but that also means that we can now design PCBs which are a great deal smaller than equivalent boards with through-hole components. As examples of this, consider the tiny microwave detector or the Arduino Multifunction 24-bit shield projects featured in this issue. They would be quite a bit larger and also more expensive if we had only used through-hole components.

But apart from SMDs, we also have the dynamic interplay of microcontroller "systems" which typically involve a family of microprocessors with a high level language and a huge library of ready-made solutions, which vast numbers of enthusiasts can apply to all sorts of problems. The key players in this arena are Arduino, Raspberry Pi and the Micromite which is now teamed with the LCD BackPack and featured in recent issues of SILICON CHIP. Reflecting this diversity, SILICON CHIP has regularly featured projects and articles on Arduino and the Raspberry Pi. Last month we had articles on all three.

So is one of these systems likely to gain the ascendancy at any time in the next 10 years? Nobody could possibly forecast that because they are all likely to change radically in that period, with all sorts of extra features and capabilities. But let's think about the particular advantages of each system.

First, there is a vast range of sensor modules (shields) available for use with Arduino microcontrollers and an attendant library of software routines which enable anyone to use them easily. But while that might be seen as a big advantage for Arduino, it is great for anyone involved in electronics, whether they are Arduino fans or not. In fact, at SILICON CHIP, we don't think of them as Arduino sensor modules; we think they are just sensor modules and they can be used in any project. In fact, the Micromite BackPack Parking Assistant project presented last month used an ultrasonic sensor module intended for use with Arduinos. A lot of Arduino modules can be used in projects where there is no microprocessor involved or any need for software. If you have tended to ignore Arduino modules, look again. Many are pretty straightforward to use.

The Raspberry Pi has taken quite a different approach and almost seems to be aiming to produce dedicated PC applications. The latest version, the Raspberry Pi 3, has even more capabilities, including built-in WiFi. It too has shields (or "hats") but nowhere near as many options as Arduino (yet).

And then there is our own favourite, the Micromite, produced by Geoff Graham. This has been around for a few years now and in some ways could be considered as a successor to the PICAXE range developed by Revolution Education in the UK. But now the Micromite has been teamed with a cheap, readily available touchscreen LCD display, in the Micromite LCD BackPack and that changes everything. Yes, there are touch-screens available for Arduino and Raspberry Pi but they tend to be larger and somewhat more expensive. And the Micromite BackPack can be programmed using easy-to-understand BASIC.

Overall, we think that the Micromite BackPack will change the design approach for a large range of electronic projects. Whereas in the past we might have produced a project with a 2-line LCD and perhaps a few (or many) switches and controls, now we can have a project which works similarly to an App on a smart phone. And while some people might hate touch-screens (they call them "smudge screens"), they can be very convenient and a lot simpler than devices with switches and potentiometers.

Which of these competing systems will win? Impossible to say. But it will be a fascinating ride in the coming decade.

Leo Simpson

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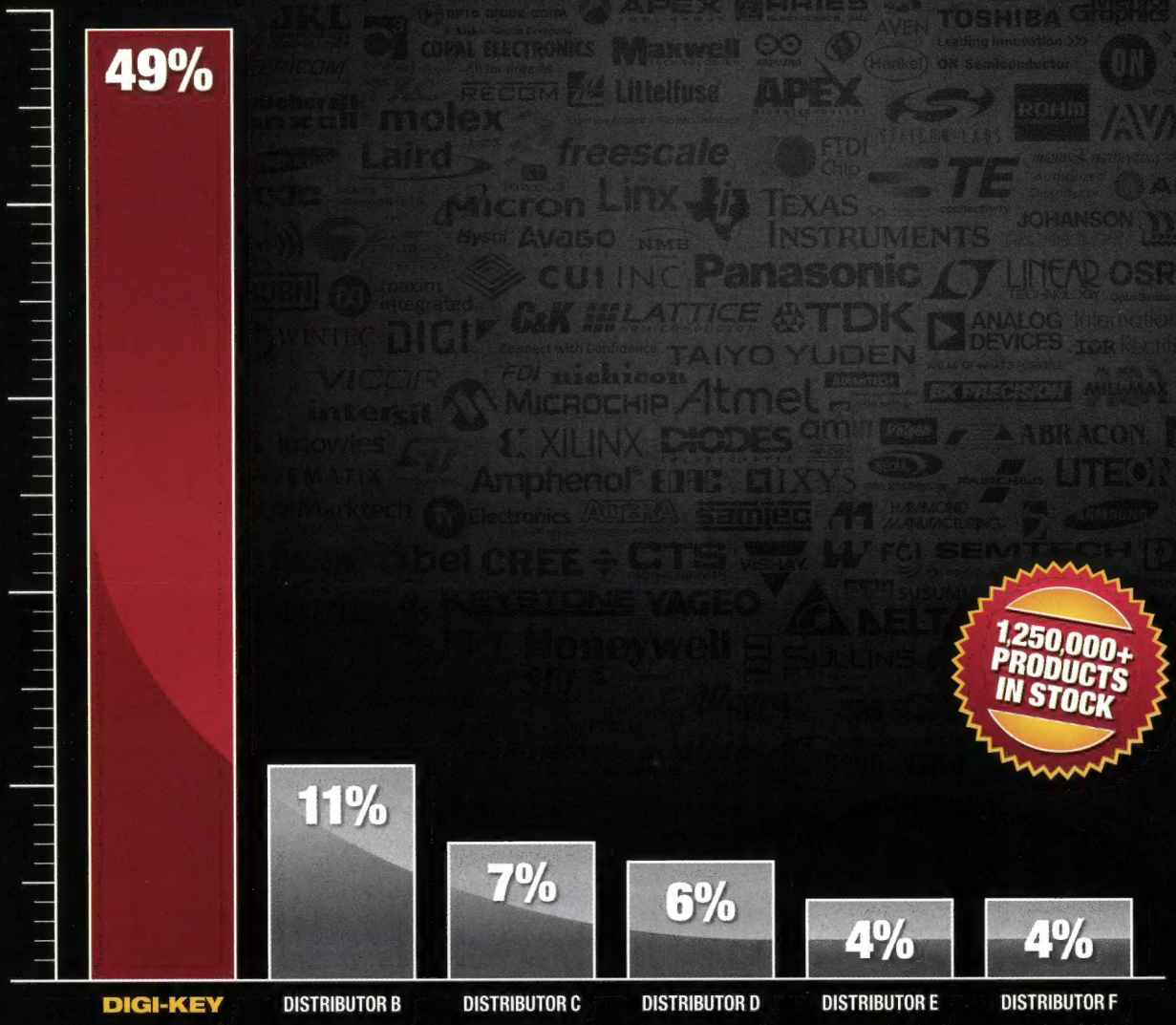

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Designing an appropriately-sized solar system

Solar systems are not rocket science but are surrounded by plenty of misinformation. I have lived with and installed solar systems for a period of over 20 years and these are my conclusions:

To select the system, you look at last year's electricity bill total, multiply by 10, add any subsidies and this is the amount to spend on the solar system.

The number of panels should be about 30% more than required. This helps to cover winter; solar panels are cheap and you get less output over the months of winter.

If the cells are mounted at between 25° and 45°, there will be no maintenance required, as normal rain will wash off any dust collected. If the panels are flat, then annual hosing to remove settled dust will be required. If you choose to live near the sea then you must expect to get corrosion effects, just as for any other appliance/building.

Life expectancy is unknown but some panel manufacturers suggest 90% output after 12 years and better than 80% after 25 years.

Buy the biggest battery you can afford. The life of the battery is determined by the number of cycles and how deep they are. If you can keep DOD (depth of discharge) to less than 10%, the batteries will approach their shelf life of 20 years. As most batteries are now sealed, no significant maintenance will be required.

You can expect electronic failures to be no worse than any other appliance, and most likely to occur in the first 12 months of operation.

Over winter, a small generator can add significant charge to the batteries, or in larger systems, you can retain the grid connection for low tariff charging over winter (at a cost). A wind turbine is very good but may not be possible in your area.

Efficient appliances (many stars) and timers will make the system more viable, as will time-shifting so that high consumption appliances are used when the sun is shining. Using air-conditioning to pre-heat/cool during the day also helps.

Multiple small air conditioners (7 stars) are more efficient than one big unit (3 stars?). There is a lot to be gained by having a 7-star house. Good insulation in the ceiling, walls and under floor really pays off, as does attention to shading and roof reflectivity. Similarly, having windows double glazed or fitted with heavy drapes and pelmets are worthwhile. Windows and doors also benefit from draft excluders.

If dismantled, the local metal recycler will buy your lead batteries for their metal, or specialist recyclers will take care of your lithium batteries, as lithium is a valuable metal. While the glass and aluminium are easily recycled (at no cost), there is now a firm that recycles and repairs whole panels.

Ignore any economist who offers to analyse the benefits, as these people seem to be predisposed to predict failure.

Enjoy your system and just remind yourself you are not paying electricity bills every three months!

David Tuck,
Yallourn North, Vic.

White LED confusion cleared up

I am unaware of any white LED with a forward operating voltage below 1.5V, as stated by Brian Critchley

Micromite LCD BackPack is a great project

After having a serious look at the latest effort from Geoff Graham, I am in awe of his skill and abilities. The Micromite and Maximite articles were absolutely top-class projects that were in, anybody's eyes, world beaters. I built a few myself.

I thought it would be difficult to top these projects but Geoff has done it again. His latest effort in the February 2016 issue is a fantastic project that has virtually unlimited uses. As a general-purpose controller, the LCD BackPack is a world first for electronic DIY projects. Its uses are only limited by one's imagination.

I can see many thousands of these being built. I will be ordering several myself. I sure wish I had the skill required to develop this project. Over the coming months, I think many projects will appear in the Circuit Design Ideas section of the magazine. My own "to-do list" has a growing number of ideas being added.

My grandsons and I have a large model railway layout. In the near future, our layout will be converted to be controlled by a few Micromites and LCD BackPacks. The level of control sophistication I plan would not be possible without Geoff and his BackPack project.

On behalf of all the electronics enthusiasts out there, both professional and amateur, I would like to thank him for his efforts. Personally I would like to say please keep up the good work in producing world class projects like the LCD BackPack. If you want to run for Prime Minister then you can count on my vote!

Jeff Monegal,
North Maclean, Qld.

Editor's note: we expected the LCD BackPack to be popular but despite this have been overwhelmed with orders for kits. We apologise to those who have had to wait while we restock and by the time this issue has been published, should have sufficient stock for all orders.

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Alternative use for Garage Parking Assistant

We have just purchased a Toyota Camry Hybrid car; the SL version with all the electronic gadgets. But the bottom of the front bumper will still scrape on the stops when parking in shopping centres. The bumper will try to ride over the stop or concrete block if you go forward too much. You can see scrapes on these blocks everywhere where this has happened to other cars.

There are ultrasonic sensors in the front bumper but they are not low enough to sense the kerb. What is needed is a unit to let us know when to stop going forward. Maybe you could publish a new project which uses the Garage Parking Assistant, suitably modified, to solve this problem – just mount the sensors onto the car with small brackets so you don't have to put sensor holes into the bumper bar.

By the way, car manufacturers don't put all the gadgets in at once, because they would not have anything to add in next year's model.

Roderick Wall,
Mount Eliza, Vic.

Editor's note: provided the ultrasonic module can be made waterproof, it can probably mounted under the front of the car in order to sense low kerbs and parking barriers.

in the Mailbag section of the February issue. Most likely, his LED lamps consist of two parallel series strings of six LEDs for the 6W unit and 10 LEDs for the 10W unit. All the white LEDs that I have measured had an operation voltage of about 3.1V across each individual LED at their rated power.

The voltage readings he obtained at the different current levels for each of his lamps are what I would expect. However, none of these currents were high enough to drive the lamps at their rated power. He apparently did not take into account the current multiplying effect of the SMPS in his calculations. Both his lamps would require a current of about 320mA to obtain full power. This would be obtained with about 18.5V across the 6W unit and 31V across the 10W unit.

The 32V 1.2A transformer that he mentions should be able to drive the 10W LED lamp near to its rated power. However, the series resistor will need to be "selected on test" to limit the current to less then 300mA. This would allow for some rise in the mains voltage without over-driving the lamp.

Stan Woithe,
Fulham Gardens, SA.

Long-range DAB+ reception

I have followed with much interest your articles on DAB+ radio and in particular, the Mailbag item from a Lithgow subscriber on long range DAB+. I embarked on a similar quest to get DAB+ reception in Narara, Gosford, NSW after enjoying DAB+ in Sydney for several years. I am situated in a valley which makes getting good reception a challenge.

By chance, I noticed one day I was getting a few DAB+ stations while outside near a temporary VHF antenna, so I investigated further. In the end, I bought a Digimatch LT3165 VHF 6-10 antenna from Jaycar (prior to your article on how to build one, unfortunately), added a Kingray masthead amplifier and ran some good coax to my Yamaha T-D500 tuner (which has useful tuning aid features).

Once the antenna was aligned to the best signal (vertically polarised, pointing south-west), I was able to pull in around 50 stations. SBS does not seem to play and ABC is a bit down on strength, however all the stations I like (eg, WSFM & 80s Classic) are coming in at 100%, and to my ears, sound great. It was well worth the effort!

Keith Morrell,
Narara, NSW.

A good article on defibrillators

I liked the Publisher's Letter and the article about defibrillators in the February 2016 issue.

I have been an instructor for St John Ambulance, WA for many years. St John Ambulance in WA provides the state's ambulance service. All their ambulances have defibrillators and all of the Perth ambulances have 12-lead ECGs, which can transmit the patient's ECG to a tertiary hospital where cardiologists read the waveforms and decide if the patient needs to be given a cardiac catheter. If so, they bypass the emergency department.

This means that the patient will be given this life-saving treatment well within 60 minutes after an attack, as recommended by the Heart Found-

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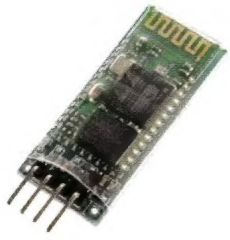

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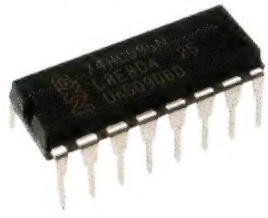

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Mailbag: continued

Defibrillators should be widely available in public places

Bravo for Leo Simpson for his advocacy for the availability of defibrillators!

My wife and I travel through Europe frequently, especially in France, where there seems to be a defibrillator available for public use even in such common places as MacDonald's restaurants!

There should be compulsory courses in the use of these devices as well as CPR, conducted at Government expense for all officials involved in group organised activities. Advertisements on television could make the public aware of how to use them and provide the devices in proscribed locations as in Europe.

Saving a life is the greatest thrill a human can experience; suffering the anguish of not having the tools to achieve this can lead to long, and deep, depression – I know this from experience.

Graeme McKenzie, via email.

ation. All country ambulances have 3-lead ECGs because they cannot get the patient to a major Perth hospital in that time.

Alan Hughes, Hamersley, WA.

Defibrillators can't save all cardiac arrest victims

I am writing this after having just read the Publisher's Letter in the February 2016 issue of SILICON CHIP. I have a medical background and have had a lifelong interest in electronics, having purchased my first Radio & Hobbies magazine in 1949. My career has involved research, teaching and design and fabrication of laboratory instrumentation, with particular emphasis on the cardiovascular system – mostly the "cardio" part.

From reading your article about defibrillators, it is clear that Leo Simpson is understandably well motivated in the promotion of these instruments, as a result of having the unfortunate experience of seeing someone die on the dance-floor. However, in those circumstances, no-one should be burdened by "pangs of guilt".

The point I would like to make is that the majority of deaths from a so-called heart attack in the older age group are not necessarily due to a malignant tachyarrhythmia such as ventricular fibrillation. It used to be the case that about 2/3 of patients suffering their first "heart attack" did not live long enough to reach hospital.

Things have improved considerably over the years but in the older age group, not by that much. This is because the most common cause of a massive heart attack is occlusion of the descending branch of the left coronary artery (sometimes called "the widow-maker"), which will simply stop the left ventricle because of a lack of oxygen and fuel to much of the myocardium.

This is a common occurrence in the older, often obese and diabetic age group. A defibrillator simply will not start a dying ventricle. That's not to say that one should not try, since a milder form of coronary occlusion may render an area of myocardium sick enough to cause, say, ventricular tachycardia, which would predispose to fibrillation.

On the other hand, the staff of modern coronary intensive-care wards frequently save lives by monitoring the ECG and by being able to rapidly respond to the development of ventricular fibrillation resulting from abnormal rhythms, caused by electrical changes in myocardium damaged by a non-lethal coronary occlusion. Thus, continuous ECG monitoring and the bedside defibrillator are essential parts of any coronary ICU (intensive care unit) environment.

The situation in the young, especially under heavy exercise stress, is very different. Collapse from asystole in these people may have been caused by previously undetected abnormal conducting pathways between the atria and the ventricles which could, under heavy sympathetic nerve stimulation of the heart, as occurs in strenuous exercise, lead to a malignant tachyarrhythmia going on to fibrillation. Clearly, a defibrillator in such a situation provides the greatest chance of survival.

Another cause of ventricular fibrillation is electrocution and of course, a defibrillator can be justified in any situation where accidental exposure to electrical currents, especially at mains frequency but also DC, can occur. When such currents pass through

the chest the chances of fibrillation are particularly high.

Yet another cause of unexpected, sudden loss of consciousness and collapse is the so-called Stokes-Adams attack, in which the patient's heart stops pumping because of complete but usually temporary blockage of the electrical conducting pathway from atria to ventricles. Usually, after a period of 30 seconds or so, the ventricles start beating again, albeit at a much slower rate (around 20bpm) as the result of the establishment of a "ventricular pacemaker". Cardiac output is re-established and the patient regains consciousness.

Such occurrences can sometimes explain the rapid revival of a pulse-less patient by CPR. These patients require a pacemaker since the attacks are unpredictable and can obviously occur in potentially lethal situations.

So there is no doubt that portable defibrillators can save lives in certain circumstances. A point worth making, however, is that if the clinical signs of brain death are there, the victim is unlikely to recover. Thus, if there has been no cardiac output for more than 3-4 minutes and the unconscious victim has dilated pupils that do not constrict in response to light, it is likely that the patient has suffered brain death. While one must try CPR, the chances of recovery are poor.

Name & address supplied
but withheld at the writer's request.

Super-critical power station queries

I'm puzzled about some aspects of the excellent article on super-critical and ultra-super-critical power stations that was published in the December 2015 issue. In May this year, I will be involved in a discussion on aspects of the topics covered in the article, which I found to be very thought-provoking.

In Table 4 (p29), "Air consumption" is listed as N/A for super-critical plants (is no air consumed?). Similarly, "Ash produced" and "Desulphurisation products" are shown as N/A for both super-critical and ultra-supercritical plants. Again, "Stack gas" is shown as N/A for supercritical plants. Surely there's stack gas emanating from a super-critical plant?

Why all of these N/A notations? Perhaps that's consistent with the very high operating temperatures? The explanation may be glaringly obvious but I haven't managed to crack the puzzle. Can you assist me, please?

Brian Graham,
Mt. Waverley, Vic.

Dr David Maddison responds: N/A in this case stands for not available. Naturally gases are produced, but my sources didn't quote any figures and I couldn't find any.

[These can be estimated as they are presumably proportional to coal consumption and CO_2 emissions – Editor].

Comments on Versatile Technology & PICs

I read the article about Versatile Technology in December's issue with nothing but admiration for Gerard Dean. Australia needs people like him and not the political and business clowns who promise everything and deliver

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Mailbag: continued

Excess PV solar energy for water heating

I've often heard people compare the merits of a stand-alone solar hot-water system, be it flat panel or evacuated tube, with the old-style resistive hot-water system. A few people now think the up-front costs of solar hot-water are so high that you are better off with a conventional resistive hot-water system powered by a solar photovoltaic system, using a time switch to heat the water during peak solar production. Depending on the size of the solar system, the hot water element possibly should be changed to 2kWh. This obviously only applies to those on the new reduced feed-in tariffs.

It would be far more preferable to monitor the excess solar power production and divert the excess to hot-water production. This could almost be achieved using a variable speed drive (low frequency = low power), but the internal control logic probably wouldn't appreciate driving a resistive load.

Using the major components from a VSD (variable speed drive), it should be relatively simple to design a circuit to divert excess power to water heating. This could make a good project. The power required to heat 315 litres of water from 15°C to 60°C is about 16kWh. This project makes more economic sense than battery storage.

A 315-litre Sanden heat pump hot-water system is the other optimum green solution but I think it costs about $4500 which will mean that the capital costs will probably never be repaid.

Personally, I have a 36-tube evacuated solar hot-water system I designed that will never pay for itself, even though it has better specifications and lower cost than a commercial unit. The system has 630 litres of total storage and the final 200 litres has an always-active electric booster. I also have a 9kW solar power system that will be fully paid off by the time we lose our 28c feed in tariff, on the 1st January 2019.

I also have daily production figures since installation in October 2012. A continuous graph of production over the past 365 days is interesting as it shows virtually no drop off in production since installation.

My daily solar generation is monitored and logged to PVOutput. I'm now in the process of logging our power consumption but this isn't easy as the solar power feeds into sub-boards and we have power drawn off before the main power board.

Greg Green,
via email.

nothing. He is a "go getter" and I love his motto of TOTAL WAR. That is how a competitive business should be conducted.

However, I do have some concerns. Versatile Technology is so similar to the business where I worked and which is now defunct. It too captured a large share of the international market and 99% of its business was overseas. Also, my boss was a go-getter and spent a large amount of his time overseas building the business but despite all the effort, it was the uncontrolled aspects of the business that caused most problems.

With almost no home market, the exchange rate had a huge effect on profits. Distance for service and maintenance was a real issue. R&D was absolutely necessary but consumed large amounts of money with long lead times for pay-back. Eventually, my boss managed to sell the business to an overseas company which closed it within a couple of years. I hope this does not happen to Versatile Technology.

On another topic, I have to agree with with Alan Cashin's comments about PIC32 processors. Just lately, I have been taking a closer look at the PIC32MZs because I need a fast, low-power maths engine. I can currently compile BASIC using Firewing for a PIC32MX320F128 @ 80MHz and I would like to be able to use a PIC-32MZxxx @ 200MHz.

But the MIPS M5150 core used in the PIC32MZ is in a league of its own. It is so different to other common processors. Basically, it is designed for high-security applications using virtualisation.

Imagination have targeted their M-5150 core towards "HD video streaming, gaming, VPN, social media, cloud computing and storage, and machine-to-machine (M2M) communication" etc and obviously Microchip is doing the same with the PIC32MZ chips. It seems that secure communications is the main drive behind the increase in complexity and in particular the separation of secure and non-secure applications.

The same internet link for home, gas and electricity metering can be used alongside normal activities. There is also the mention of Digital Rights Management and it is obvious that implies enforcement. If of interest, the following links are for the M51xx family and Imagination's FlowCloud pages. Both pages have PDFs of general information:

https://imgtec.com/mips/warrior/m-class-m51xx-core-family/
http://flow.imgtec.com/developers/docs/white-papers

George Ramsay,
Holland Park, Qld.

LED lamp reliability

In the Mailbag section of the February 2016 issue, Brian Critchley, of Elanora, examined two short-lived 220/240VAC LED lamps of 6W and 10W and concluded that they are not a dead loss as the LED arrays may survive for other lighting jobs in the hands of interested readers.

As an initial assumption, he suspected that the LEDs are simply wired in series but his observations can be interpreted differently.

White LEDs have a forward voltage of about 3.3V when fully illuminated and 10W between 20 LEDs suggests they are 0.5W each, a common SMD size. The 10W lamp contained a dud power supply and an array of 20 LEDs mounted on a 40 x 2mm aluminium disc to fit the lamp profile. In series, the array voltage would exceed 60V, too much for the 50V capacitor he found in the power supply.

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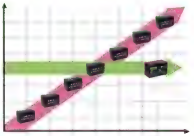

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SMBUS CABLE 1	SMBus Comm. Cable M12 to RJ45. 660mm.	**SMBUS CABLE 5**	SMBus Comm. Cable M12 to Molex 2510. 560mm.
SMBUS CABLE 2	SMBus Comm. Cable JST XHP-4 to RJ45. 660mm.	**SMBUS CABLE 6**	SMBus Comm. Cable JST XHP-4 to Molex. 300mm.

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Mailbag: continued

Valve biasing & guitar amplifiers

You published my query regarding adjustable valve biasing in the Ask Silicon Chip pages of the January 2016 issue and I subsequently saw the "Adjustable current sink for valve biasing" item in the Circuit Notebook pages of the March edition. Please pass on my regards and appreciation to Herman Nacinovich for his effort. The circuit design was exactly what I was hoping for.

I also read the comments by Hugo Holden in March's Mailbag and appreciate the technical argument for fixed bias. I have used this method on many occasions and particularly for higher wattage push-pull circuits where clean power is required. However, my subjective opinion for guitar is that it doesn't sound as good under break-up conditions where the valve is operating above and below cut off. I also use a bypass capacitor across the cathode resistor.

It seems there has been an interest in valve amplification of late in Silicon Chip. I'm wondering if you guys have considered doing a valve guitar amplifier kit. Most dedicated guitar speakers now are very efficient; the one I use in my designs is rated at 103dBA/W @ 1m. So you can get very loud volume levels for very few watts.

My single-ended design pushes out 20W using a KT88 valve and a customer I have sold this to uses it at gigging volume levels. The only disadvantage is that being single-ended, the output transformer is relatively expensive.

The power transformer I use for my 20W design is rated at 60W, provides output voltages up to 320V @ 100mA, has supply for heaters (3A) and even an 18V output (for switching circuits). The cost is just $38 US plus $17 for shipping; see **www.analogmetric.com/goods.php?id=78**

So realistically, a 15W push-pull guitar amplifier (using the same output transformer as the Currawong) could be produced relatively cheaply. The only question is how elaborate a preamplifier? The power transformer heater winding will power up to five ECC83 valves, leaving an additional 1.5A for the power valves.

James Carlon,
Point Cook, Vic.

B.C. found that the array began to conduct at about 26V (25.8V at 25mA). This suggests two sets of 10 series LEDs in parallel and that the failed 10W PSU would have delivered about 33V at 300mA total, ie, 150mA per set, fully illuminated.

On the other hand, the 6W array began to conduct at only 16V. This suggests similarly that the 12 LEDs are wired as a parallel combination of two sets of six series LEDs. At 6W rated power, the combined forward voltage will be about 20V at 300mA (150mA per set of LEDs).

Without air circulation, the LED discs will run fairly hot, so a heatsink will be required. The power requirements of these units are within the capacity of plugpack style supplies so we can agree with B. C. that such recycled LED arrays can live longer than their short conventional lives.

By the way, an occasional contributor to, and advertiser in Silicon Chip, sells 32mm by ~1mm discs fitted with 6 x 0.5W series/parallel LEDs (3W, 10V at 300mA) and 50mm x 1mm discs with 10 x 0.5W LEDs (5W, 16.5V at 300mA). Two such discs, adequately driven and heatsinked, would approximate the light output of B. C.'s recycled 6W and 10W lamps. They are very bright and are ideal to illuminate a work surface in the kitchen or caravan.

John Crichton,
Portland, NSW.

Appreciation for Stereo Valve Preamplifier

I have built the Stereo Valve Preamplifier from the January & February 2016 issues. Congratulations to Nicholas Vinen on a fine design. I am playing mine through a Silicon Chip Class-A stereo amplifier and it is quite superb. I have also run it with an SC480 amplifier (Silicon Chip, January & February 20133) and again it is flawless. I even prefer it to my existing Silicon Chip Studio Series Preamplifier.

Of course, high fidelity requires a decent source and matching speakers and these, in my experience, are usually the weak links in any system. Silicon Chip designed electronics surpass any commercial products I could afford. Keep up the good work

Graeme Dennett,
Melba, ACT.

Raspberry Pi project enthusiasm

Your recent projects using the Raspberry Pi were well-timed; just what I needed to "get it out of the box" and do some "baking" (aka programming). I have already ordered a (second) Raspberry Pi/Sense Hat and Wi-Pi from element14.

I have been a Pi fan for some time – got my first one up and running some time ago and I suppose I have been waiting for a nudge and a project to move forward. Thanks.

By the way, in regard to mounting the Sense Hat remotely, I would suggest making up an IDC lead with a 20-way female connector at either end and then use a pin header to change it into a male connector, eg, you could use the Jaycar HM3250 (remove the plastic spacer). Alternatively, Altronics have an Extra Height Header, Cat. P5406.

Mike Abrams,
via email.

Comment: thanks for the feedback. Note that the Raspberry Pi 3 has just been released and it has onboard WiFi (802.11n) and Bluetooth, as well as a much more powerful 64-bit quad-core processor.

Car technology roll-out purposefully slow

I share Leo Simpson's frustration that many of the electronic innovations in cars do not seem to use the full potential of such innovation, and I can offer an explanation.

Having worked as a design engineer for an Australian manufacturer of cars, it was a source of annoyance that the product planners always wanted to keep something "up their sleeve" for the next model or the next update. We were never permitted to design and

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Mailbag: continued

Australian manufacturing & disagreements over loudspeaker operation

On the issue of manufacturing in Australia, SBS recently aired a documentary film about James Cameron's dive to the Challenger Deep (approx. 11km). For those unfamiliar with James Cameron, he has directed many Hollywood blockbuster movies including Terminator 2, Titanic, True Lies, Rambo, Aliens and Avatar.

The vessel was designed by Australian Ron Allum and built in Leichhardt. It used "an underwater acoustic communication system developed by West Australian company L-3 Nautronix" (Wikipedia). This is world-class technology.

Regarding the operation of loudspeakers, the reply to P. T.'s query on page 94 of the February issue contains some significant errors, in my opinion:

"So if you apply a sinewave signal, there is no tendency for the coil to over-travel and its motion is a very good analogue of the input signal. Consider what would happen if there was a tendency for the coil to overshoot (and there always is, in fact)."

So is there or isn't there? That could have been better expressed! At resonance there is a significant possibility that the cone will overshoot; that is the nature of resonances. But to more substantive matters.

The output impedance of the amplifier is in series with the voice coil, and so the voice coil impedance must be included as part of the damping impedance. Actually, it is only the resistive portion of these impedances that deliver any damping, since damping is the result of dissipation of energy (which reactive components cannot do).

Since the amplifier output resistance is so small compared to voice coil resistance, it is actually the voice coil that contributes nearly all the electrical damping of the loudspeaker and the amplifier usually has virtually no effect (on damping). This is less true for valve amplifiers which may have output resistances of several ohms.

It has been pointed out by experts years ago (Douglas Self, for example) that damping factor is a parameter of dubious utility for rating an amplifiers' performance, and it has no significant role in damping loudspeaker motion. In fact, it is probably the mechanical environment of the loudspeaker (eg, the cabinet, the listening room etc) which provides the bulk of the damping.

While it is true that "a loudspeaker is inherently inductive" (discounting piezo and electrostatic speakers for the moment, which are inherently capacitive), they should be predominantly resistive over most of their working frequency range.

Furthermore, if the loudspeaker impedance exhibits any resonances or other peaks and troughs in the impedance curve (say, from the effects of crossover networks or impedance normalising circuits), then at frequencies on one side of the peak (or trough) they will look inductive but on the other side they will look capacitive. At resonance the impedance should be purely resistive.

"Finally, consider that the air trapped in the speaker box also tends to modify the motion of the cone, damping more for reverse excursions than forward motion."

I think this is flat out false for two reasons. First, the air in the box acts as a spring and, as such, is not dissipative; therefore it provides little or no damping. Second, if the air acted differently in one direction to the other, it would be non-linear and would introduce significant distortion to the sound.

Ideally, the air inside the box applies the same force to cone excursions in either direction but it applies positive differential pressure when the cone moves back and negative differential pressure (ie, lower pressure than outside the box) when the cone moves forward.

"Again, this is where the amplifier is supposed to maintain tight control over the motion of the cone . . ."

No, as I explained above, this doesn't happen, the amplifier is largely prevented from damping the cone motion by the voice coil impedance. In fact, it is the air trapped behind the speaker that provides most of the damping effects and curiously, not so much by outright damping, make the best possible vehicle at that point in time.

In effect, the makers were playing the buying public for fools and never giving quite as much as they could. With the Australian automobile industry all but gone, and many overseas makers under a cloud as to integrity and prosperity, one wonders whether it is the auto makers who are the fools.

David Inkster,
Meadows, SA.

Problem with video to USB converter

I also experienced much trouble trying to make the Easycap video to USB Converter work (Ask SILICON CHIP, September 2015, page 106.) I purchased a converter through eBay and found I could not make it work. I then purchased a second converter from a second seller, and found the drivers on the disc would not load, because the CD was very warped.

The seller was very helpful and said I could download the drivers from Dropbox. I could not find these drivers on Dropbox, so the seller gave me a link to a website. These drivers were corrupt when I downloaded then, so the seller gave me another link, but this driver zip had missing files when unpacked. Each download was about 600MB and my monthly limit is 2GB. I returned the converters to both sellers and received refunds.

I did lose money on the transaction but I had some satisfaction in being able to leave negative feedback, hopefully to warn others. I did wonder if the sellers made their money from buyers who did not ask for a refund. Eventually I took my home movies to a video production company who burnt my movies to DVD for $40.

Tony Farrell,
Kingscliff, NSW.

but by shifting the inherent resonance in the speaker up to a frequency where the real damping components (such as losses in the suspension structure) are more effective.

Fully-sealed speakers tend to exhibit smaller resonances than ported speakers, at least partly because fully sealed speakers shift the resonance further in frequency, the down-side being that fully sealed speaker systems tend to have a higher low-frequency cut-off.

"That is why it is most important, in a hifi system, to have very low resistance loudspeaker connecting leads."

No, that is not the reason. In a JAES engineering report ("Effects of Cable, Loudspeaker and Amplifier Interactions"), Fred Davis says that low resistance and low inductance are important parameters for loudspeaker cables and the driving amplifier, to the extent that motor vehicle jumper cables (which have very low resistance) are not appropriate. He states "The best response was obtained with low-inductance cables and an amplifier with low-inductance output and a high, frequency-independent damping factor."

The reason is that excessive inductance makes the frequency response roll off at high audio frequencies. It has little or nothing to do with damping and the resistance was not the lone determining parameter of performance. The three best performing cables were 6, 7 and 8 AWG, while the worst performer was 7 AWG jumper cables. 12 AWG cable performed better than a 3 AWG cable. While low resistance is generally good, it should not be the sole criterion for selection of suitable loudspeaker cable. "Very low resistance" is not as essential as low inductance.

Phil Denniss,
Darlington, NSW.

Comment: it is true that typical solid state amplifiers have output impedances which are very low compared to the voice coil resistance of a typical loudspeaker. But any voltage generated by "incorrect" motion of the loudspeaker cone will still be heavily damped by the output impedance of the amplifier. In effect, it will be shorted out and the error current will be limited by the voice coil resistance.

Nor is it correct to think of the air in an enclosure as simply being a spring. When a volume of gas is subjected to rapid variations in pressures, due to the motion of the loudspeaker cone, there will inevitably be energy losses and the result is damping of the cone motion. SC

LOOKING FOR A PCB?

PCBs for most recent (>2010) SILICON CHIP projects are available from the SILICON CHIP On-Line Shop – see the On-Line Shop pages in this issue or log onto

siliconchip.com.au/PCBs

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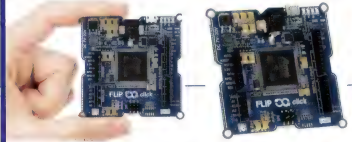
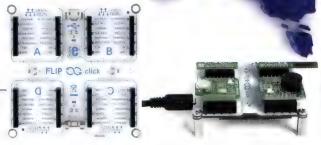


Arduino's two-sided cousin. While it may share many of the same attributes as the popular, open source platform including the 32-bit AT91SAM3X8E core of a Due, the pinout of an Uno and the ability to be programmed in the Arduino IDE via via microUSB, what really sets this new dev board from MikroElektronika apart is when you turn it over.



You'll find four mikroBUS sockets for "click boards." With more than 160 to choose from, Makers can prototype their next gizmo or gadget effortlessly by simply adding new functionality — ranging from Wireless, OLED displays to relays to sensors. That's 160^4 product combinations to set your imagination

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Einstein's 100-Year-Old Relativity Theory Proved!

A few weeks ago, scientists announced that they had finally proven the last, elusive bit of Einstein's General Theory of Relativity, with the observation of Gravitational Waves arriving at the Earth from a cataclysmic event in the (very!) distant past. But what are Gravitational Waves and why are they relevant?

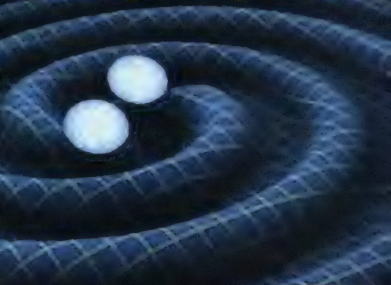


Image courtesy NASA

Gravitational Waves: "The scientific discovery of the 21st century"

by Ross Tester

Most parts of Einstein's General Theory of Relativity were relatively (pardon the pun!) easy to demonstrate and/or prove. But one part, the existence of gravitational waves, proved not only elusive but impossible to confirm given the lack of equipment at the time – even until quite recently. They remained just a theory, even though Taylor and his student Hulse earned a Nobel prize for Physics in 1933 for "proof" of their existence.

These waves carry information about their dramatic origins – and about the nature of gravity itself – that cannot otherwise be obtained.

Now for the first time, scientists in the USA, with more than a little help from researchers at the University of Western Australia, have detected gravitational waves by the twin Laser Interferometer Gravitational-wave Observatory (LIGO) detectors in both Livingston, Louisiana, and Hanford, Washington.

LIGO, first proposed in the 1980s as a means of detecting gravitational waves, is a consortium of more than 1000 scientists from 90 universities in 15 countries.

The University of Western Australia team has spent the past seven years putting together gravitational-wave detector equipment.

The detectors in the USA use powerful lasers to measure vibrations of mirrors suspended four kilometres apart at the ends of huge vacuum pipes.

UWA researchers contributed to the project by using high power lasers at the Gingin Gravitational Research Centre to observe and test newly-discovered ways of scattering the laser beams. They developed methods for preventing instabilities in the detectors.

A major upgrade to LIGO increased the sensitivity of their instruments compared to the first generation, enabling a large increase in the volume of the universe probed – and the discovery of gravitational waves during its first observation run.

Physicists have concluded that the detected gravitational waves were produced during the final fraction of a second

of the merger of two black holes to produce a single, more massive spinning black hole. This collision of two black holes had been predicted but never observed.

A few false starts

"Discoveries" of gravitational waves have been announced a few times in the past. In the 1960s, an American physicist, Joseph Weber, claimed he had detected them but no-one could reproduce his methodology so his findings were discredited.

Then as recently as 2014, a team at the South Pole reported evidence of the waves but their results turned out to be from cosmic dust.

And as reported overleaf, excited LIGO scientists were about to report they had detected gravitational waves . . . but their joy was short-lived when they discovered their data had been "hacked" as part of the LIGO quality control.

But now it appears to be real

Announcing the discovery to the world's media, David Reitze, LIGO executive director, said "Ladies and gentlemen, we have detected gravitational waves. We did it. The things we've surmised and speculated about will become the subjects of detailed study."

To say the world's scientists were excited by the announcement would be a massive understatement. Already, there is a huge amount of information on the 'net about gravitational waves and what their discovery will mean.

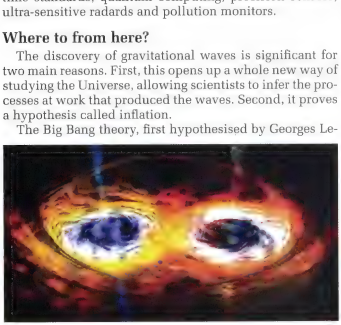
Indeed, a Google search only a few days after the news broke in February last revealed more than 16 million results, many of them attempting to describe just what gravitational waves were!

Yet more reports showed how far this research has already spread. It is being applied to mineral exploration, time standards, quantum computing, precision sensors, ultra-sensitive radards and pollution monitors.

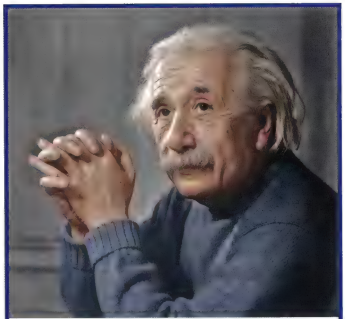
Where to from here?

The discovery of gravitational waves is significant for two main reasons. First, this opens up a whole new way of studying the Universe, allowing scientists to infer the processes at work that produced the waves. Second, it proves a hypothesis called inflation.

The Big Bang theory, first hypothesised by Georges Le-



Computer-generated image of the moment before two black holes collide. In those last microseconds, an enormous amount of energy is released, generating gravitational waves. Until now, they've been theoretical – but have now been detected. See the video – and much more besides – at www.theverge.com/2016/2/11/10965312/einstein-gravitational-waves-discovered-announced-video



What are Gravitational Waves?

In 1916, the brilliant theoretical physicist Albert Einstein (pictured above) discovered a mathematical way to explain gravity – and called it his general theory of relativity. Part of this theory predicted the concept of gravitational waves.

General relativity states that mass distorts both space and time in the same way a heavy bowling ball will distort a trampoline.

When any object accelerates, it creates ripples in space-time, just like a boat causes ripples in a pond (and also similarly an accelerating electrical charge produces an electromagnetic wave). Even *you* moving about will, according to the General Theory of Relativity, distort space-time.

These space-time ripples are gravitational waves. They are *extremely* weak so are very difficult to detect. In fact, any ripple *you* cause would be so weak it would (with today's technology) be utterly impossible to detect.

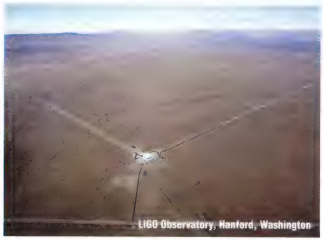
It takes something with an *immense* mass, far bigger than anything we can imagine, to produce a gravitational wave of any significant magnitude. Scientists have long believed that the best hope of detecting gravitational waves here on Earth would come from two black holes or pulsars collapsing into each other. But even that was not enough – to detect them, a huge breakthrough in technology was also required.

And thus it was with the Gravitational Waves detected on September 14, 2015: the waves came from the very last microseconds of a pair of black holes colliding out in space 1.3 billion years ago, with a force beyond anyone's comprehension. It was this force which created the ripples detected on Earth and brought a smile to thousands of scientists the world over.

Why? Gravitational Waves are important in telling us about the origins of the universe – a snapshot, if you like, of the universe only a few hundred thousand years after it started.

Indeed, "primordial" gravitational waves, which were generated in the first moments of the universe, would carry vital information about how the universe began

Although there was strong circumstancial evidence of their existence they had never been detected . . . until now.


LIGO Observatory, Hanford, Washington

LIGO Observatory, Livingston, Louisiana

The LIGO Observatories. . . and Australia's AIGO

LIGO is the world's largest gravitational wave observatory and a "cutting edge" physics experiment. Unlike optical or radio telescope observatories, though, LIGO is "blind". LIGO's detector is a laser interferometer – it is designed to detect unbelievably tiny changes in laser light reflected from unbelievably high precision mirrors at each end of a vacuum "tube". Unbelieavable? Almost!

It cannot see electromagnetic radiation like other observatories (eg, light, radio waves, X rays, etc). But the data collected will have far-reaching effects on a variety of physics fields, including gravitation, relativity, astrophysics, cosmology, particle physics and nuclear physics.

The LIGO collaboration has two widely-separated observatories in the USA, one north-west in Washington (state) and one south-east in Louisiana (both shown above). These are funded by the National Science Foundation. Incidentally, LIGO stands for **L**aser **I**nterferometer **G**ravitational wave **O**bservatory.

Each facility is shaped like a giant "L"; the "arms" of the L are two vacuum-sealed 1.2m-diameter tubes stretching 4km long, with mirrors at each end. Each of the tubes is encased in a 3m-wide concrete enclosure to protect it from interference.

When a gravitational wave passes, one mirror gets closer while the other retreats; scientists measure this phenomenon by bouncing lasers off the mirrors. Changes in the amount of time it takes a laser to bounce off a mirror indicate a gravitational wave.

We're talking about measuring changes almost beyond our comprehension – equivalent to a couple of millimetres in $1x10^{23}$m.

The gravitational wave measurements from the black holes were also converted into audible form, what LIGO calls a "chirp." Just as the black holes merge, the frequency of the resulting gravitational waves increases up until the moment of collision. As a sound, that movement becomes a high-pitched note that sweeps through the octaves really quickly (it's been likened to the note from a cello).

The gravitational waves only move LIGO's instruments by about one ten-thousandth the size of a proton. This means Earth isn't the ideal place to look for waves, since movements from people or traffic can potentially cause interference.

For instance, LIGO kept getting "readings" that were actually the result of cars rolling over a nearby bump in the road.

A couple of years ago, LIGO operators created "fake" gravitational waves to see if they were detected. The excited scientists were just about to announce their "discovery" to the world when it was revealed that it was all part of LIGO quality control!

However, it would appear that the latest discovery is the "real deal", the holy grail that has eluded scientists for 100 years.

Australian AIGO

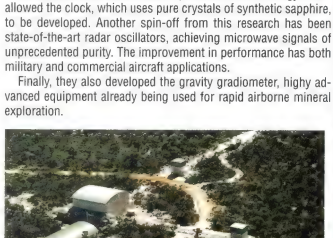
The University of Western Australia is one of the partners in LIGO. In 1990, the UWA School of Physics established the Australian International Gravitational Observatory (AIGO) at Gingin, north of Perth.

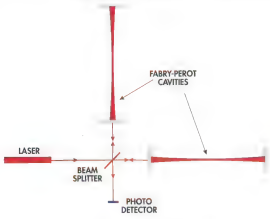
Through strong national and international participation, the research centre concentrates on the development of advanced technologies driven by the goal of the next generation large scale gravitational observatory construction.

As well as their primary objective of gravitational wave research, one spin-off was the development of the Sapphire Clock, the only one in the world stable enough to allow atomic clocks to reach their ultimate precision. These are required for the International Space Station for the next generation of precision GPS navigational systems.

Gravity wave detection research provided the technology which allowed the clock, which uses pure crystals of synthetic sapphire, to be developed. Another spin-off from this research has been state-of-the-art radar oscillators, achieving microwave signals of unprecedented purity. The improvement in performance has both military and commercial aircraft applications.

Finally, they also developed the gravity gradiometer, highy advanced equipment already being used for rapid airborne mineral exploration.


AIGO Research Centre, Gingin, Western Australia



Simplified diagram of a laser interferometer. The idea is that gravitational waves will push the mirrors apart one way and contract them the other, enabling precise measurement using the laser.

maitre, a Belgian priest and physicist, was called "the day without yesterday" because it was the moment when time and space began. However, not all matter could have come from the Big Bang (as originally conceived).

In the 1970s, cosmologists came up with another theory, called inflation, which suggests that in the infinitessimally small time after the Big Bang there was a sudden enlargement of the universe.

Only inflation can amplify the gravitational wave, so formed, to make it detectable. So if gravitational waves have been detected, inflation must have taken place.

The scientists at LIGO have opened up a whole new field of astronomy – gravitational wave astronomy, that in time will let us see way back in time; everything from the heart of a black hole to the moments after the big bang.

It's akin to when radio telescopes were invented – they opened up the sky with millions of new radio sources that were previously unknown.

Gravitational wave research will further expand man's knowledge of the universe, no doubt leading on to yet more discoveries.

Into space?

Because of the errors and distortions caused by earth-bound observation, the next step will be to establish gravitational wave detection in space.

Last December, the LISA Pathfinder mission (a partnership between NASA and the European Space Agency) launched a spacecraft to test the technologies needed for future space-based detectors, thus elminating earthly disturbances and interference.

Instead of 4km-long interferometers, in space they could be literally millions of kilometres long. The larger the interferometer, the smaller the gravitational wave it can detect.

And there's a lot more room up there!

Watch . . . and learn!

If you're struggling with the concept of gravitational waves, the three-minute animated video at www.independent.co.uk/news/science/gravitational-waves-simple-explanation-video-a6869761.html is among the best we've seen and well worth watching! SC

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Touch-Screen Boat Computer With GPS

Would you like an accurate digital speedometer for your boat? One with a large clear display? This low-cost unit with touch control is just the shot. It can also display a raft of other information, including your heading, location and the relative bearing to a point of interest, which can be anything from the harbour entrance to a great fishing spot.

AS WITH THE Garage Parking Assistant described last month, this project is based on the Micromite LCD BackPack. However, for this project, we've deleted the ultrasonic sensor and substituted a low-cost GPS module. By adding a suitable BASIC program, it now functions as a boat computer which will display your speed as well as a selection of other data on its colourful LCD panel.

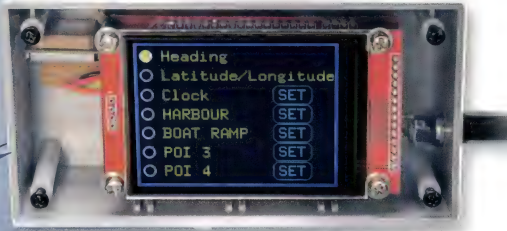
Most SILICON CHIP readers will be familiar with the Micromite LCD BackPack which was featured in the February 2016 issue. It combines a low-cost, touch-sensitive colour LCD panel with the Micromite, a cheap but powerful microcontroller programmed in the BASIC language. It uses less than a dozen components and can be built in under half an hour.

The only extra component required for our Touch-Screen Boat Computer is a GPS module and these are now very

Fig.1: this is the main display shown on the Boat Computer when it first powers up. The top half of the screen shows the speed in knots, while the bottom half shows the current heading. The data in both halves can be configured by touching either the top or bottom half of the screen.

Fig.2: touching the top half of the screen shown in Fig.1 switches the speed indication from knots to km/h.

Fig.3: touching the top of the screen again displays the speed in mph. Another touch brings it back to knots.



This photo shows the list of data that can be shown in the lower half of the main display. Touching any option switches the unit back to the main display, with the relevant data displayed in the lower half of the screen. Touching a SET button allows you to configure a particular entry (ie, to set the clock or configure a point of interest (POI).

By Geoff Graham

cheap – as low as $10 or even less. The "special sauce" which makes these two parts work together as a boat computer is the BASIC program which takes the data from the GPS module and formats it for display on the LCD.

As emphasised in the original Micromite Backpack article, the advantage of BASIC is that it is easy to understand and it is written in plain text. So if you do not like how the program works, you can jump in and change it to suit your own needs.

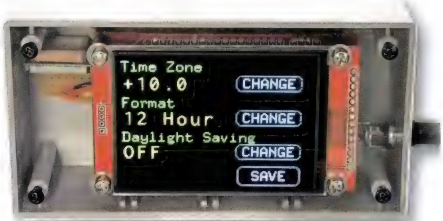
Even if you have no intention of building the Touch-Screen Boat Computer, you might find some of the BASIC program useful for other projects. For example, the keypad routines can be used in many other applications and you are welcome to copy this part of the program (or any other part) for your own designs.

Information display

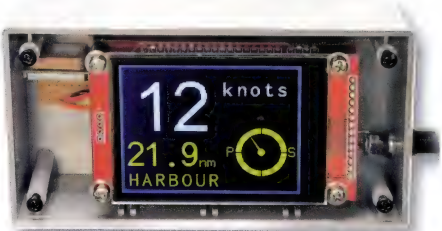
Because the Boat Computer makes extensive use of its graphical display for setting the various options, its operation is intuitive. On power-up, the display is divided into two "panels". The top half of the screen shows your speed while the lower half can be used to display a selection of other information, including the current heading, latitude/longitude, time and more. The photo on the facing page shows a typical display.

When the top half of the screen (showing the speed) is touched, the speed display will switch from knots to km/h. A second touch will then change the reading to mph, while touching it again brings the reading back to knots. The selection will be remembered (as will any other changes that are made), even if the power is removed.

Conversely, when the bottom half of the screen is touched, a listing of all the possible display modes will be shown (see above photo). Touching an item in this list will select it and the Touch-Screen Boat Computer will then revert to the main display, with the newly selected data shown below the speed.



This photo shows the display after the SET button has been pressed for the time entry. It allows the time zone to be set, as well as the format for displaying the time (12 or 24-hour). It also allows you to select for daylight saving, in which case one hour is added to the displayed time.



This is what the main screen looks like when a point of interest (POI) has been selected for the lower half. It shows the distance and the direction to the selected POI, in this case one named HARBOUR. To navigate to the POI, all you need do is steer in the direction of the pointer and watch the distance as it counts down to zero.

Some entries have a SET button alongside them. When touched, this will allow you to customise the settings associated with that particular display. All settings are saved in non-volatile memory and will be reinstated on power up.

The various items that appear in the list when the bottom half of the screen is touched are as follows:

Heading: this will show the boat's current heading both in degrees and as a compass rose with a pointer. The GPS module uses forward movement to calculate the heading, so the boat needs to be moving for this display to work.

Latitude/longitude: this will display the current latitude and longitude in degrees, minutes and seconds.

Clock: this will show the time accurate to within a second. The SET button allows you to change the time zone, the format (12 or 24-hour) and to enable daylight saving compensation (one hour is added when this is on).

POI 1 to POI 4: four different points of interest (POI) can be saved in the Touch-Screen Boat Computer. When one of these is selected, the bottom half of the main display will show the distance to the POI and the relative bearing as a pointer.

The POI can be anything that you might want to navigate to. Typical examples include a harbour entrance, a boat ramp or a good fishing spot. To navigate to the POI, all you need do is follow the pointer and watch the distance as it counts down to zero.

Each POI entry has a SET button which allows you to set the name for the POI (using an alphanumeric keyboard) and its latitude and longitude. You can also set the POI to your current location – which is handy if you have found a good fishing spot and may want to return.

Demonstration mode

There might be occasions when you would like to use the Touch-Screen Boat Computer without a GPS module or without a lock on sufficient satellites to get a display. For example, you might to explore the menu system without a working GPS module.

To enable this, you can put the unit into demonstration mode and **that's done by touching the centre of the screen while the power is applied.** The LCD will then display "Demo Mode" as the unit powers up. The device will then display an artificial speed, location, time, etc. This data is static (ie, it does not change as you might expect) but it is useful for exploring the menus and features of the Touch-Screen Boat Computer.

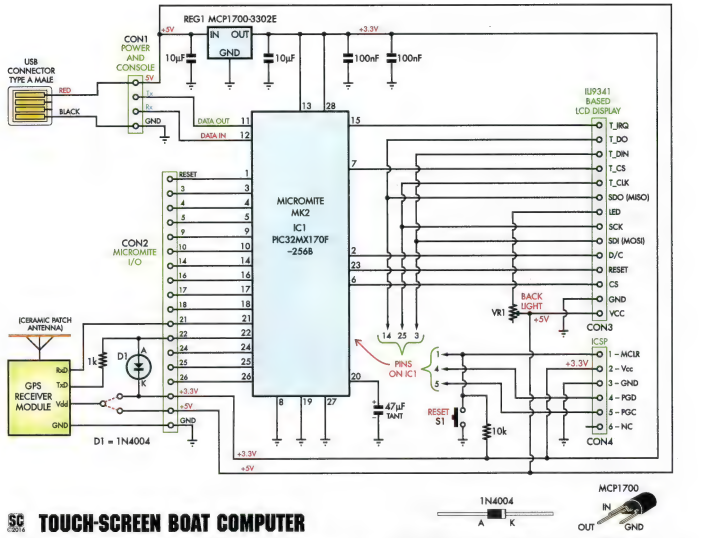
Because you don't need a GPS module in demo mode, you can try the software on any Micromite LCD Backpack, even if you're not planning on building the Touch-Screen Boat Computer. Exploring the software may give you ideas for your own projects and you can then extract sections of the BASIC program for your own use.

Selecting a GPS module

It's difficult to specify a particular GPS module for the unit, as manufacturers are constantly discontinuing older models and introducing new versions. To counter this, we have made the unit as flexible as possible, so that it can accommodate almost any GPS module on the market.

Most GPS modules require either a 3.3V or 5V power supply and the Micromite LCD Backpack can provide both, so that isn't a problem. Depending on the particular module, the speed of the serial interface can vary from 4800 baud to 38,400 baud. To accommodate this, the BASIC program automatically detects the speed that the module is using (within that range) and sets the interface speed accordingly.

Another variation between modules



TOUCH-SCREEN BOAT COMPUTER

Fig.1: most of the work in the Touch-Screen Boat Computer is done by IC1 which receives data from the GPS module and formats it for a touch-screen colour LCD connected to CON3. Power comes from a 5V DC USB charger and this directly powers the LCD, while 3-pin regulator REG1 provides 3.3V to power IC1. The GPS module is powered by either 5V or 3.3V (depending on the module), while diode D1 and the 1kΩ resistor in series with the GPS module's Tx lead are there to protect IC1 if the GPS module uses RS-232 signalling (rather than TTL).

is that some use TTL-level signalling while others use RS-232. Again, the BASIC program will automatically adjust for whatever standard the module uses. Note, however, that some GPS modules have a USB interface and the Touch-Screen Boat Computer cannot work with these.

TTL signalling means that the data will swing from 0V to about 3V, while the output will be at 3V at idle (ie, when there is no signal). RS232 uses the same signalling sequence as TTL but the voltage swings from -12V to +12V, with idle being -12V (ie, it is inverted with respect to TTL).

GPS modules can also vary in the messages that they send and many of these messages are unique to a particular manufacturer. To avoid this issue, the Touch-Screen Boat Computer uses only the RMC message. This message (and its format) is specified as mandatory in the NMEA 0183 standard for GPS hardware, so all GPS modules will produce this signal (the unit will ignore any other messages).

Our prototype used a Fastrax UP501 GPS module (mostly because we had one in our parts box). Another suitable module is the USGlobalSat EM-408 which has been used in many SILICON CHIP projects in the past. Unfortunately, both these modules can be difficult to obtain these days.

More readily-available GPS modules include the Ublox NEO-7M-C and NEO-6M , the Skylab MT3329/SKM53 and the V.KEL VK16HX.

In summary, when selecting a GPS module, look for these characteristics: 3.3V or 5V supply rail, 4800 to 38,400 baud rate and a TTL or RS-232 serial interface. In most cases, you will want to choose a module with an inbuilt patch antenna. This takes the form of a flat square ceramic object on the top of the module.

Having an inbuilt antenna makes it simpler to use the module and in most installations, this antenna will gather enough signal to do the job. If the module does not include an antenna, you then have the flexibility of choosing a separate waterproof antenna which could be mounted externally with an unobstructed view of the sky.

Some modules have other peculiarities. For example, the UP501 that we used requires an external 3V battery to

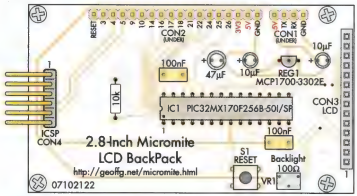


Fig.2: repeated from the February 2016 issue, this parts layout diagram shows how to build the BackPack PCB for the 2.8-inch LCD. Note that pin headers CON1 & CON2 are mounted on the rear of the PCB, while CON3 & CON4 are mounted on the top (see photos).

The colour LCD is mounted on the clear acrylic lid before being plugged into the BackPack PCB. Be sure to fit the LCD to the lid with the correct orientation.

keep its memory alive when the power is removed. **Most other GPS modules have this battery incorporated inside them, so this is a rare requirement.**

In addition, some GPS modules have an enable input and this must normally be connected to the supply voltage (ie, pulled high). In some cases though, this input should be left floating or even grounded, so check the specifications for your particular module when connecting it to the circuit.

Many modules also feature a 1pps (pulse per second) output but this can be safely ignored.

To make things simple, you can purchase a suitable module from the Silicon Chip Online Shop.

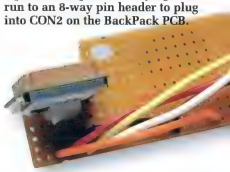
Circuit details

Fig.1 shows the circuit diagram for the Touch-Screen Boat Computer, including the Micromite LCD BackPack.

IC1 is the Micromite which is based on a PIC32MX170F256B microcontroller. It does all the work of taking the data from the GPS module and formatting it for display on the colour LCD which connects to CON3.

Power for the circuit is derived from

The GPS module can be mounted on a piece of strip-board & flying leads run to an 8-way pin header to plug into CON2 on the BackPack PCB.



a 5V DC USB supply, while low-power voltage regulator REG1 provides a 3.3V rail for IC1. Diode D1 and the 1kΩ resistor in series with the GPS module's transmit (TxD) pin are there to protect IC1 if the module uses RS-232 signalling.

However, if you are sure that your GPS module uses TTL signalling, then D1 can be dispensed with and a link used instead of the 1kΩ resistor.

The circuit has provision for powering the GPS module from either 5V DC or 3.3V DC (from REG1), depending on the module's supply requirements.

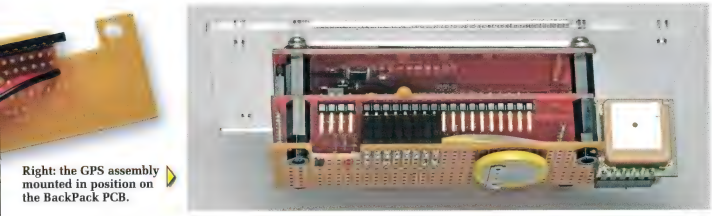
Construction

Building the Touch-Screen Boat Computer mainly involves building the Micromite LCD BackPack, as detailed in the February 2016 issue of Silicon Chip.

Assembling the BackPack PCB is quite simple; just follow the parts layout diagram shown in Fig.2 (as originally published in the February 2016 issue) or the silk screen overlay on the PCB. The 2.8-inch version is the one to build and the job should only take about half an hour.

All GPS modules have a different mounting method, so this is something that you will have to figure out, depending on the module that's being used. **The main consideration when mounting the GPS module is that it should be positioned so that the antenna is horizontal, with its top surface facing the sky, when the boat computer is being used.** This will ensure maximum sensitivity.

As stated, our prototype used a Fastrax UP501 GPS module and this was mounted on a scrap piece of stripboard. The module was first soldered to a 6-way pin header and this was then plugged into a 6-way female header. This header was then connect-



Right: the GPS assembly mounted in position on the BackPack PCB.

ed via flying leads to an 8-way female header mounted along one edge of the board and positioned so that it could be plugged into CON2 (ie, between pin 21 and GND) on the Micromite. The accompanying photos show the details.

As mentioned above, this particular GPS module also needed a back-up battery for its internal memory and this can also be seen in the photographs.

Loading the firmware

Loading the firmware and the BASIC program is basically a 4-step process:

Step 1: program the MMBasic firmware into the chip using a PIC32 programmer (eg, a PICkit 3).

Step 2: connect to the Micromite's console and, using the OPTION commands, configure MMBasic for the LCD display and the touch function.

Step 3: load two fonts into the Micromite and save them in the library.

Step 4: load the Boat Computer program.

Saving the two fonts into the library is something that needs explaining. The library is a special memory area in the Micromite where fonts and program modules can be stored. When these are saved to the library they are, for all intents and purposes, added to the MMBasic language.

They do not show when a program is listed and they are not deleted when a new program is loaded. However, they are available to any program, just the same as the features of MMBasic are always available to any program that is loaded.

One very useful feature of the library is that anything saved into it is compressed. That's why it's necessary to load the two fonts separately from the BASIC program and save them to the library.

The fonts are quite large and there is not enough memory in the Micromite to load both the fonts and the program at the same time. This means that we must first load the fonts and save them to the library, where they will be compressed. We can then load the main program (which relies on the two fonts being available) into main memory.

As with last month's Garage Parking Assistant, you have a few choices when it comes to loading the firmware. You can combine all of the above steps into one by downloading the file ***BoatComputerFull.hex*** from the SILICON CHIP website and programming it into a blank PIC32 chip using a PICkit 3. This file has the Micromite firmware, the settings for the LCD panel, the two fonts and the BASIC program all combined into one hex file.

Using this method of loading the firmware makes the job easy because the one operation will completely set up the microcontroller to be a boat computer.

Pre-programmed chip

An even easier option is to purchase a pre-programmed PIC32 microcontroller from the SILICON CHIP Online Shop. Then, all you have to do is plug the chip into its socket and it will be ready to go (no programming needed).

Programming in steps

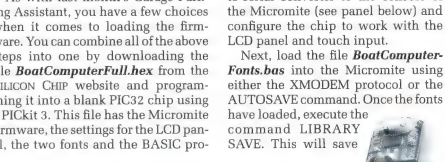
Yet another option is to go through all four steps individually. First, download the file ***Micromite_V5.1.hex*** from the SILICON CHIP website and program it into the PIC32 microcontroller using a PICkit 3. That done, connect a USB-to-serial converter to the console of the Micromite (see panel below) and configure the chip to work with the LCD panel and touch input.

Next, load the file ***BoatComputer-Fonts.bas*** into the Micromite using either the XMODEM protocol or the AUTOSAVE command. Once the fonts have loaded, execute the command LIBRARY SAVE. This will save ever power is applied and after the program has been run once you should never need to use the console again.

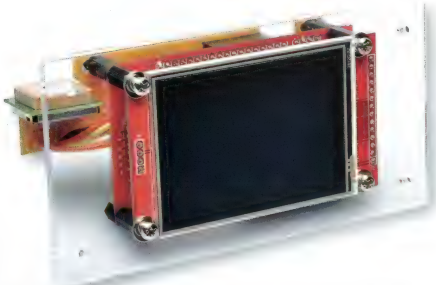
Loading BASIC

If you are going to load the BASIC program yourself or edit it later, you will need to make up a cable with a USB-to-serial converter as described in the February 2016 issue (or in the Micromite User Manual). This is powered from a 5V USB supply via a cable fitted with a micro-USB connector.

After you have the program running to your satisfaction, you can then unplug the converter and use the power cable shown in Fig.4 instead. This is because the program is designed to start running automatically when-



The USB-to-serial converter should be connected via colour-coded flying leads to a 4-way header socket, so that it can be plugged into CON1 on the underside of the BackPack PCB. Use a red wire for +5V, white for TX, yellow for Rx and black for GND.



The prototype used stacked M3 washers between the LCD module and the lid but a single spring washer at each corner is a better solution (see text). Be sure to run a thin bead of silicone around the edge of LCD before fitting it to the lid, to ensure a water-tight seal.

the fonts in the library and remove them from main memory. You can confirm this by running the command MEMORY, which will show that about 12KB of memory has been allocated to the library and there is nothing in the main program memory.

Finally, load the BASIC program ***BoatComputer.bas*** using either the XMODEM protocol or the AUTOSAVE command. All the files listed above are available from the SILICON CHIP website.

The process for loading MMBasic, configuring the interpreter and loading BASIC programs was detailed in the article describing the Micromite LCD BackPack in the February 2016 issue. It's also explained in the Micromite User Manual, which is included in the Micromite firmware zip file.

When you have run through all four steps described above, the result will be exactly the same as if you had programmed a blank chip with the combined file ***BoatComputerFull.hex*** (or purchased a pre-programmed chip).

Be aware, however, that the touch calibration in the combined firmware file (and in pre-programmed PIC32s) was done with a reasonably standard LCD panel. Most panels require similar parameters for calibrating the touch-sensitive screen but yours might require re-calibration if it is significantly different from the "standard".

If you use the combined firmware file and find that the touch calibration is inaccurate, you can correct this by connecting a USB-to-serial converter to the console, halting the program with CTRL-C and re-running the calibration as described in the original Micromite LCD BackPack article in February 2016.

Don't worry if you don't have this article. The Micromite User Manual (included in the firmware zip file available from the SILICON CHIP website) also contains a full description of the calibration procedure. In fact, you should download the manual in any case, as it fully documents the Micromite and what you can do with it – and that's a lot.

Testing the GPS module

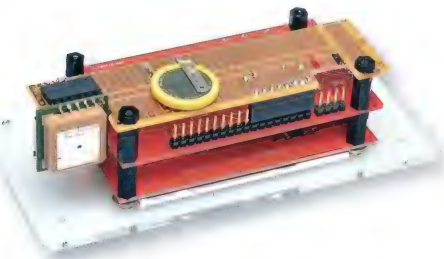
In most cases, you will be able to connect the GPS module to the Micromite Backpack and it will just start running without drama. When the Boat Computer is first turned on, you will see the message "Waiting for GPS" on the LCD panel. This means that the BASIC program is searching for the baud rate being used by the module.

If after 10 seconds you see the message "GPS Module Not Found" it means that the BASIC program has tried all the possible baud rates and TTL/RS-232 combinations and did not find the module. The software will then keep searching but you obviously need to diagnose the issue.

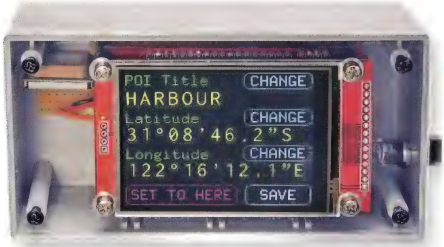
In most cases, the cause will be incorrect wiring or an enable input to the GPS module that needs to be permanently connected to the supply voltage or to ground (check the specifications for your module). To investigate what is going on, connect the unit to a PC via a USB-to-serial converter, enter the following program into the Micromite via a terminal emulator (eg, Tera Term) and run it:

```
OPEN "COM1:9600" AS #1
DO
  PRINT INPUT$(1, #1);
  T$ = INKEY$
  IF LEN(T$) THEN PRINT #1, T$;
LOOP
```

Replace the 9600 with whatever baud rate you want to use. If you suspect that the module is using RS-232,



The GPS module used in the prototype required a separate back-up battery and this was also mounted on the strip-board. If you don't need a separate battery, you can simply glue the GPS module to the top of the case and run flying leads to an 8-way pin header to connect to CON2 on the BackPack PCB.



This is the set-up screen for a point of interest (POI). The title of the POI and its latitude and longitude can be changed by touching the CHANGE button beside each entry. A useful feature is the SET TO HERE button which will set the coordinates to your current location – handy if you have found a good fishing spot.

This photo shows the display after touching the CHANGE button for a POI Title. It allows you to change the title given to a POI. Touching a button will insert that character while touching the red left/right triangles will scroll through the alphabet.

you should tack `,INV` on the end of the baud rate, eg:

```
OPEN "COM1:9600,INV" AS #1
```

When you run this program, anything that the GPS module outputs will be echoed on the console, so you can see exactly what the unit is receiving. The accompanying panel "Understanding A GPS Module's Output" provides further information on the content of the messages that you should be seeing.

Using the above program, you can also send commands to the module. Anything that you type on the console's keyboard will be sent to the module. For example, the following will reset a module using the SIRF chipset to its factory default settings:

```
$PSRF104,00,00,00,00,00,00,12,
08*29
```

All commands sent to the module (including the above) must be terminated with a Ctrl-M character, followed by Ctrl-J (ie, carriage return/line feed). Use Ctrl-C to exit the test program.

Finding satellites

When the Touch-Screen Boat Computer receives valid data from the GPS module after power-up, the displayed message changes from "Waiting For

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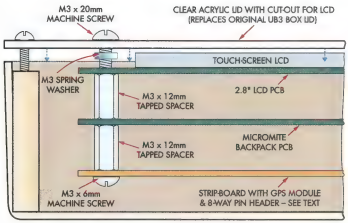


Fig.3: here's how to attach the LCD & Micromite BackPack PCB to the clear acrylic lid. The LCD goes through a cut-out in the lid and sits flush with its top surface.

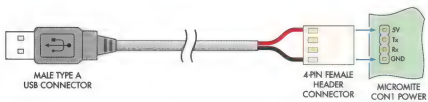


Fig.4: the Touch-Screen Boat Computer is powered from a 5V USB charger that's either plugged into a 12V cigarette lighter socket or wired permanently into the boat's power supply (see text). To make a suitable power cable, cut off one end of a USB cable, thread the cut end through a cable gland in the side of the case and solder it to a 4-pin female header connector.

GPS" to "Searching for Satellites". This means that the GPS module is working and is scanning for satellites in order to get a fix (this requires at least four satellites).

You could be waiting for a while here so don't panic if nothing happens immediately. When a GPS module is first turned on, it must download details of the satellite's orbits which are encoded on the GPS signal. **Receiving the full set of data takes 12.5 minutes and if there is a corruption in the signal, it could take a lot longer.** The answer is to take the unit outside with a long power lead, place it so that it has an uninterrupted view of the sky and give it half an hour or more.

When this data has been received, the module will save it in its battery-backed memory so that, at next power-up, the module finds the satellites much faster (normally within 10-15 seconds). However, this data does change with time so if you have not used your Touch-Screen Boat Computer for some time, it might have to go through the whole process of loading fresh orbital data again (with a corresponding delay).

You will know when the module has found sufficient satellites to locate your position because the "searching" message will disappear and the display will switch to showing your speed and heading.

Enclosure

Building the unit into an enclosure is left until after the LCD BackPack assembly and GPS combination has been thoroughly tested. Once that's done, it can be housed in a UB3 plastic enclosure fitted with a clear laser-cut clear acrylic lid. This lid is available from the SILICON CHIP Online Shop and is supplied with all the necessary mounting holes and a precision cut-out for the touch-screen LCD panel.

An important feature of the enclosure is that, while the LCD touch-screen must be accessible, it must prevent salt spray (or even salt-laden air) from reaching the interior.

The fit between the edges of the LCD and the cut-out in the acrylic lid is very close and this is the secret to spray-proofing the enclosure. Before mounting the LCD panel, the idea is to run a thin bead of transparent silicone sealant around the edge so that when it's mounted on the acrylic panel, the sealant will fill this small gap and render the front spray-proof.

Once the sealant has cured it will be difficult to remove the LCD panel so make sure that the Touch-Screen Boat Computer is working properly and that the LCD panel and the Micromite BackPack correctly fit in the box before taking this final step. It may be necessary to trim the row of 14 solder joints on the top of the LCD module, so that they don't interfere with the lid.

Fig.3 shows the how it all goes together. The first step is to attach the LCD panel (without the BackPack PCB) to the acrylic lid at each corner using an M3 x 10mm machine screw, an M3 spring washer and an M3 x 12mm tapped spacer. The spring washers must be placed between the acrylic lid and the display's PCB so that the LCD panel will be flush with the surface of the lid. **Note that the cut-out in the lid**

This view shows the unit with the latitude and longitude option selected for the lower half of the display. Changing the displayed data is easy.

Understanding A GPS Module's Output

One of the difficulties when troubleshooting a project using a GPS module is understanding what the data coming from such a module should look like. The following is the output that we recorded from the Fastrax UP501 module. These six lines are repeated every second.

First, this is the output when the module was searching for satellites (ie, it did not have a "lock" on our position):

```
$GPGGA,232048.764,,,,,0,3,,,M,,M,,*41
$GPGSA,A,1,,,,,,,,,,,,,,,*1E
$GPGSV,3,1,10,19,76,148,20,17,49,140,18,06,41,044,24,24,40,226,*7A
$GPGSV,3,2,10,15,28,286,,13,27,331,,28,25,106,,12,22,249,*7B
$GPGSV,3,3,10,02,18,001,,30,09,043,*7F
$GPRMC,232048.764,V,,,,,0.27,0.00,150216,,,N*43
```

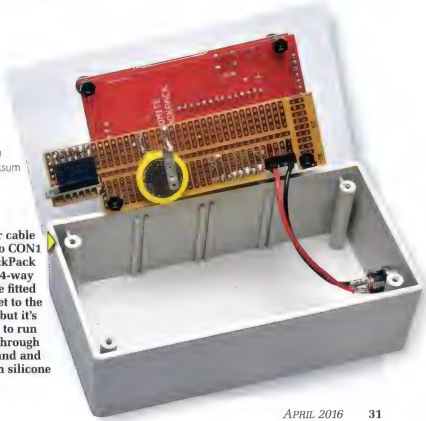
And this is the output when it did have a lock and was producing valid data:

```
$GPGGA,231719.000,3411.5204,S,14135.6619,E,1,9,0.90,3.2,M,5.1,M,,*75
$GPGSA,A,3,02,13,17,30,15,24,06,12,28,,,,2.43,0.90,2.25*03
$GPGSV,3,1,11,19,77,147,,17,51,140,16,06,40,043,29,24,39,226,10*74
$GPGSV,3,2,11,13,28,330,16,15,28,284,14,28,26,107,21,12,21,251,14*7A
$GPGSV,3,3,11,02,16,001,19,30,11,043,15,01,01,148,*48
$GPRMC,231719.000,A,3411.5204,S,14135.6619,E,9.62,302.03,150216,,,A*75
```

Each line (called a message) provides a set of data such as the current location, the number of satellites being used, etc. For the Touch-Screen Boat Computer, we only use the RMC message which is the last line in the above listing. RMC stands for "Recommended Minimum Specific GNSS Data" and is specified in the NMEA standard as mandatory; therefore, all modules from any manufacturer should generate at least this message.

Each message line is broken down into fields, with each field separated from the next by a comma. Using the above capture as an example, this is the meaning of each field:

$GPRMC:	The header designating that this is an RMC message
231719.000:	The UTC time in the format hhmmss.sss
A:	A flag indicating if the module has a satellite "lock". A = lock or V = searching
3411.5204:	The current latitude in the format ddmm.mmmm
S:	North/South indicator
14135.6619:	The current longitude in the format dddmm.mmmm
E:	East/West indicator
9.62:	Current speed in knots
302.03:	The current heading in degrees
150216:	The UTC date in the format ddmmyy
,,,:	These two fields are for specialised data not used (ie, empty) in most modules
A:	Another specialised field indicating the mode of the GPS module
***75:**	The * character marks the end of the data and the following two digits are the checksum



The power cable connects to CON1 on the BackPack PCB via a 4-way header. We fitted a DC socket to the prototype but it's preferable to run the cable through a cable gland and seal it with silicone (see text).

for the LCD is offset to the left so that the active area of the LCD is centred horizontally.

The easiest way to go about the assembly is as follows:

Step 1: run a very thin bead of silicone around the outside top edge of the LCD;

Step 2: sit the LCD panel on a horizontal surface and carefully place the four spring washers in position. They can each be held in place with tiny blob of silicone;

Step 3: place the lid in position over

Parts List

Micromite LCD BackPack Unit

1 PCB, code 07102122, 86 x 50mm (for 2.8-inch LCD)
1 ILI9341-based LCD, 320 x 240 pixels, 2.8-inch diagonal
1 UB3 ABS box, 130 x 67 x 43mm (Altronics H0153 or H0203, Jaycar HB6013 or HB6023)
1 laser-cut clear acrylic lid to suit UB3 box
1 4-pin tactile switch, through-hole
1 100Ω vertical-mount side adjust trimpot (Altronics R2579, element14 9608044 or similar)
1 28-pin DIL low-profile IC socket
1 4-pin 0.1-inch male header (CON1)
1 18-pin 0.1-inch male header (CON2)
1 14-pin 0.1-inch female header socket (CON3)
1 6-pin 0.1-inch right-angle male header (CON4)
1 4-pin 0.1-inch female header
1 8-pin 0.1-inch female header
4 M3 x 12mm tapped spacers
2 M3 x 6mm machine screws

Semiconductors

1 PIC32MX170F256B-50I/SP microcontroller programmed with *BoatComputerFull.hex* (IC1) – see text. Note: a PIC32-MX170F256B-I/SP can also be used but will be limited to 40MHz
1 Microchip MCP1700-3302E/TO voltage regulator (REG1)

Capacitors

1 47µF 16V tantalum or SMD ceramic (3216/1206)
2 10µF 16V tantalum or SMD ceramic (3216/1206)
2 100nF monolithic ceramic

Resistors (0.25W 5%)

1 10kΩ

Cable Parts

1 USB cable with a male type A connector (length to suit)
1 4-pin 0.1-inch female header

Additional Parts For The Boat Computer

1 3.3V or 5V GPS module (available from Online Shop – see below)
1 1N4004 silicon diode (D1)
1 1kΩ resistor (0.25W, 5%) (see text)
1 USB cable with a male type A connector on one end
1 4-pin 0.1-inch female header
1 3-6.5mm cable gland (Jaycar HP0720, Altronics H4304A)
4 No.4 x 10mm self-tapping screws
2 M3 x 12mm tapped spacers
4 M3 x 20mm machine screws
2 M3 nuts
4 M3 spring washers

Where To Buy Parts

A kit for the Micromite LCD BackPack is available from the SILICON CHIP Online Shop. This includes a 2.8-inch touch-screen LCD panel, the BackPack PCB, a PIC32 microcontroller programmed with *BoatComputerFull.hex* and all other on-board parts.

A clear acrylic lid with a cut-out to suit the LCD and mounting holes to suit a UB3 Jiffy box is available separately.

We are also offering two different GPS modules with internal battery back-up – see the SILICON CHIP Online Shop for more details.

The Micromite BackPack PCB and a programmed microcontroller can also be purchased separately.

Note that the kit does not include the box, mounting hardware, power supply, cable gland, off-board headers and connectors or cable parts.

the LCD and feed the four M3 x 20mm mounting screws through the holes; **Step 4:** secure the assembly by screwing on the four M3 x 12mm tapped spacers.

Because of the need to fit the washers, this procedure is a bit fiddly. Take your time and be careful to ensure that you don't get silicone everywhere.

Once the LCD panel has been mounted and sealed, the Micromite BackPack PCB can be plugged into CON3 on the LCD board and secured in place using M3 x 12mm tapped spacers.

As mentioned earlier, the GPS module will need to be mounted separately according to the needs of the module that you are using. This could involve mounting the module on a scrap of strip-board as we did or perhaps simply attaching it to the top of the case using silicone sealant and running flying leads to a header that plugs into CON2 of the Micromite Backpack.

Firmware Updates

For firmware updates for the Micromite and the Touch-Screen Boat Computer, please check the author's website at geoffg.net/micromite.html

Power supply

The Touch-Screen Boat Computer is powered from a 5V USB charger with an output of 500mA or more. Versions which plug into a 12V cigarette lighter socket are fine in this role.

If you wish to permanently connect the unit to your boat's 12V or 24V wiring, you can use one of the many step-down power supply modules available on eBay for just a few dollars (search for "Buck Converter"). Alternatively, use one of our USB Charger Regulators described in the July and September 2015 issues.

To make a cable for a USB charger, cut off one end of a USB cable (retaining the type A male connector on the other end) and thread the cut-off end through a cable gland fitted to one side of the UB3 ABS box. The red wire is then soldered to one pin of a 4-pin female header connector, while the black wire goes to the other end – see Fig.4.

The other two wires in the USB cable (generally green and white) can be cut short as they are not needed.

Once the cable has been completed, plug the header into CON1 on the BackPack PCB, making sure that the red wire goes to the +5V pin. The cable gland can then be tightened to make a moisture-proof seal. As an added measure, some silicone sealant can also be smeared around the cable gland inside the case.

Note that the cable gland must be fitted close to the rear of the case, so that it doesn't interfere with the BackPack PCB. Note also that you will need to secure the lid using four No.4 x 10mm self-tapping screws (the original case screws are too short with the new lid).

Finally, for the sake of convenience and to allow us to use the power cable made for the Garage Parking Sensor, we fitted a DC socket to the prototype. However, this arrangement is not moisture-proof and we strongly recommend running the power cable through a cable gland, as described above. SC

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Don't get zapped!!! Test it with this . . .

Microwave Leakage Detector

Just because your microwave oven still looks shiny and new does not mean it is safe. It could be leaking lots of microwave energy, potentially putting you at risk of being zapped. Now you can easily test it with our tiny Microwave Leakage Tester. As a bonus, it will also test WiFi access point activity.

DO YOU SLAM the door of your microwave oven after you have used it? Of course, you do! Everyone does! That repeated slamming can damage the integrity of the mesh inside the glass door so that as time goes by, the shielding becomes less effective, allowing some microwave radiation to leak out around the edges.

In particularly bad cases, enough RF could leak out to cause injury. Since RF energy is invisible, the question becomes how do you know whether your microwave oven is still safe?

Basically, you need to run our Microwave Leakage Detector around the edges of the door while the oven is operating, to check that it's safe. The level of microwave leakage (field strength) is indicated with an 8-LED bargraph. As the microwave oven is operating (and the turntable is rotating), you will see a surprising variation in leakage as you run the microwave detector around the door edges.

The detector is powered by a lithium button cell with low drain and no standby current.

This unit can also be used to check whether 2.4GHz transmitters, such

as those in WiFi routers, are active. If the Detector is held up to the base station antenna, its LEDs will flicker in response to network activity and the number of LEDs lit will indicate the transmission power level.

Operation

Essentially, a microwave leakage detector is a type of AM radio receiver tuned for signals around 2.5GHz, with an indicator of the RF field strength. Because we're mainly concerned with indicating the presence of fields and whether they are above a certain hazard power threshold, we don't need a very complex circuit. Issues such as distortion, bandwidth, linearity and so on are not important.

The basic principle of this detector is based on an article published in the July 1979 issue of *Electronics Today International* (ETI). A dipole antenna is formed from two collinear tracks on the PCB, with each track's length being one-quarter of the wavelength for 2.5GHz signals (12cm). A "hot-carrier" Schottky barrier detector diode is used to detect the signal and its output is filtered by a 220pF ceramic capacitor.

Two low-value inductors, comprising zig-zag tracks on the PCB, connect the detector diode to the filter capacitor. These prevent the capacitor's low impedance from excessively loading the dipole and also enhance the filtering operation of the capacitor at microwave frequencies.

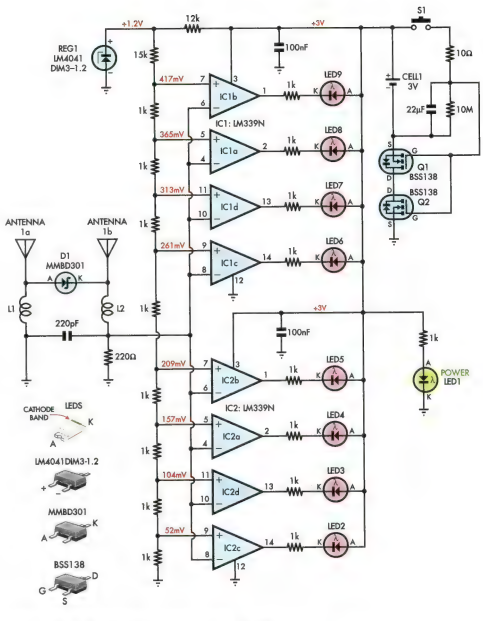
The original ETI project used a tiny moving-coil analog meter (as used in squillions of tape recorders in those days) to display the received signal strength. This had the advantage of making the device entirely passive, ie, the received RF energy operated the meter and thus no battery was required.

However, while this was cheap and simple in those times, it would now result in a fairly bulky and moderately expensive unit, with the meter costing around $17.50 today. Our new design can be built for less than that in its entirety.

Instead of an analog meter, we're using an 8-LED bargraph driven by two quad comparators, powered by the CR2032 lithium button cell.

Since you're only going to use this tester for a few minutes now and then, the button cell should last for years. The SMD parts used are compact and relatively inexpensive. The LEDs respond very quickly so you can easily see if the field is steady or pulsed and they're bright and easy to see, even at arm's length.

Having said that, if you wanted to, you could simply fit the detector diode, filter capacitor and loading resistor and measure the voltage developed across it with a multimeter (available for under $5). It's up to you; this is the cheapest and simplest option but of course, will be somewhat more awkward to use.



SC 2016 MICROWAVE LEAKAGE DETECTOR

Fig.1: the circuit of the Microwave Leakage Detector. The dipole consisting of Antennas 1a & 1b picks up ~2.5GHz radiation and this is rectified by D1 and filtered by L1, L2 & the 220pF capacitor. The voltage developed across the 220Ω load resistor is indicated by a LED bargraph consisting of red LEDs2-9 which are driven by quad comparators IC1 & IC2. The whole unit is powered from a 3V lithium button cell and switched on (for a minute or two at a time) by pressing switch S1.

Circuit description

The complete circuit is shown in Fig.1. The dipole antenna is shown at left, connected to either end of the MMBD301 UHF diode. This then feeds the 220pF filter capacitor via low-value inductors L1 & L2. One end of the filter capacitor is grounded, while

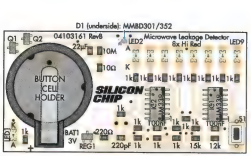


Fig.2: follow this PCB layout diagram and photo to build the Microwave Leakage Detector. All parts except for detector diode D1 go on the top of the board and most are SMDs, the exceptions being BAT1 and S1. The dipole antenna is on the bottom layer and is visible along the top of the board, as are the two zig-zag tracks that form the inductors below it. During construction, watch the orientation of IC1, IC2 and LEDs1-9. (Note: photo shows prototype board).

WARNING

DO NOT PUT THIS DETECTOR INSIDE A MICROWAVE OVEN AND TURN IT ON. IT WILL BE DESTROYED IMMEDIATELY!

You may think that this is a silly warning but we understand that Dick Smith Electronics had a number of similar kits returned in a rather melted condition because people had done just that!

the other is loaded with a 220Ω resistor. The voltage developed across this resistor depends on the microwave field strength.

This voltage is fed to the inverting inputs of eight comparator stages, based on two LM339 quad comparators which are cheap and will run from a 3V supply. The non-inverting inputs are connected to a resistor ladder which provides a series of linearly increasing voltages to each subsequent comparator stage. These are derived from a 1.2V reference voltage from REG1, which is reduced to around 417mV by a 15kΩ resistor, in combination with the 8kΩ resistance of the ladder.

If the voltage across the 220Ω load resistor is above 52mV, the output of IC2c will go low, pulling current through LED2 (the left-most red LED) and its 1kΩ current-limiting resistor. This resistor sets the LED current to around 1mA, sufficient for a high-brightness SMD LED to be quite visible. Similarly, if the voltage goes above 104mV, LED3 also lights, and so on. Above 417mV, all eight red LEDs (LED2-LED9) will be lit.

LED1 is on while ever the circuit is powered and similarly draws around 1mA. IC1 & IC2 together draw around 1mA, for a total quiescent current of around 2.4mA and a maximum current draw of just over 10mA, with all LEDs lit.

REG1 is a shunt regulator (like a zener diode) and is fed from the 3V battery via a 12kΩ resistor, which sets the nominal current level to (3V - 1.2V) ÷ 12kΩ = 150μA. The current through the ladder is 1.2V ÷ (15kΩ + 8kΩ) = 52μA. That leaves around 100μA of bias current for REG1; the minimum specified for proper operation is 60μA. This means the circuit should work OK even if the cell voltage has dropped to 2.55V (which would make it quite flat).

The remaining components protect against a reversed battery and provide the power switch-on and auto-off timer. Mosfets Q1 & Q2 are connected back-to-back (ie, in inverse series) so that they will block current flow from the battery regardless of its polarity.

With correct battery polarity, when switch S1 is pressed, the 22μF capacitor charges to a positive voltage via the 10Ω resistor and this brings the gates of Q1 and Q2 high, switching them on and powering the circuit. The 22μF capacitor is slowly discharged by its 10MΩ parallel resistor and once its voltage falls below the on-threshold of Q1 & Q2 (around 1.25V), the circuit shuts down. LED1 dims and eventually goes out.

If the battery is inserted backwards, pressing S1 simply pulls the gates of Q1 and Q2 negative with regards to their source terminals, which only serves to switch them off harder, so nothing should be damaged; the circuit simply won't operate.

To calibrate the circuit, we simply adjusted the value of the 220Ω load resistor until a full scale reading was reached with fields just strong enough to set off the alarm on a commercial microwave leakage detector we purchased.

Construction

The Microwave Leakage Detector is built on a double-sided PCB coded 04103161 and measuring 64 x 32mm. Most parts are surface-mount and all but one are fitted on the top side of the board. The exceptions are the battery holder and power switch (both through-hole parts) and the RF diode (D1) which is soldered on the underside. Refer to the PCB overlay diagram, Fig.2, during assembly.

Start by fitting the SMDs on the top side, beginning with the two ICs. Note that these are orientated with pin 1 towards the bottom of the board. Pin 1 is normally indicated with a divot or dot in the corner of the part but if there is no such marking, then you will instead need to identify the side of the package with the bevelled edge. Pin 1 is on that side.

Melt a little solder onto one of the IC pads, then slide the IC into place while heating that solder. Check its orientation and pad alignment. If both are good, solder the diagonally opposite pin. Otherwise, re-heat the initial joint and nudge the part into place.

Finally, solder all the remaining pins and don't forget to add a little solder or flux to refresh the initial joint. If any of the pins are bridged with solder, clean them up with some solder wick. A small dab of flux paste will help this process.

Next, solder REG1, Q1 and Q2 in place. These are in more or less identical packages (SOT-23) so don't get them mixed up. Use a similar technique as for IC1 & IC2. Then fit the four ceramic capacitors. These are in

The dipole antenna etched into the PCB works well but you can improve the sensitivity by soldering four 30mm lengths of wire to the pads on either side of D1, as shown here. Keep the wires straight; our got a little bent during photography.

2 x 1.2mm (2012/imperial 0805) packages with no markings. The same basic technique as described above will work for these too.

Follow with the resistors, which are similar in size to the capacitors but have their value printed on top in tiny text. You will need a magnifying glass to read it.

The nine LEDs are next; eight red and one green (LED1). These are in larger packages at around 3.2 x 1.6mm. Use a DMM set on diode test mode to determine which end is the cathode – when the LED lights up, the black probe is connected to the cathode. Solder the LEDs with this end towards the "K" on the PCB. Note that LED1's cathode faces towards the top of the PCB while LED2-LED9 are soldered with their cathodes facing the bottom.

Now you can flip the PCB over and fit D1 before fitting the final two components, BAT1 and S1, on the top side.

Testing

Insert the CR2032 cell into the holder, with the positive side up. Press S1 and check that green LED1 lights up. It should stay lit for a minute or so, then dim and eventually go out. Red LEDs LED2-LED9 should remain off. If they switch on, either there is something wrong with the circuit or you are in a rather strong microwave field and should probably move!

Most constructors will have access to a WiFi router of some sort and this is the easiest way to test the device, especially if you have the type with one or more external stub or whip antennas. With the unit switched on, hold it up alongside one of the router's antennas with its on-board dipole aligned with the antenna.

Assuming there is some network activity (and there usually will be, if only because the router is broadcasting its SSID), you should see some of LED2-LED9 light up and flicker as the router transmits bursts of data. Depending on how close you're holding the device, some bursts may be strong enough to light up all eight LEDs while others may result in just a few LEDs lighting. Bursts that light up all LEDs aren't necessarily hazardous as they will be quite brief, so the total radiated energy should be low.

Rotate the unit and note how quickly its sensitivity drops if it is not aligned with the radiated field. This is why, when checking a microwave oven, you will need to rotate the device as you move it around the oven.

Improving the antenna

While the dipole etched into the PCB works, we found that by soldering four 30mm lengths of thin, stiff insulated wire to the pads on either side of D1, the detector can be made less sensitive to antenna orientation. Basically, two of the pieces of wire are soldered directly in parallel to the PCB tracks while the other two are perpendicular, sticking out the front and back of the board (see photo).

We used Kynar but you could also use "bell wire", which is a light-duty solid copper core insulated wire that was historically used for telephones. Make sure that it can't short to anything – you may need to insulate the ends with some thin heatshrink or a dob of silicone sealant.

It's still a good idea to hold the board so that one dipole or the other is in the assumed field direction. However, even if it's not quite perfectly aligned, you're more likely to get a reading with this arrangement.

This does make fitting heatshrink tubing over the PCB somewhat more tricky but it can still be done. You would need to solder the two parallel antenna wires, fit the tubing, shrink it down, then cut a couple of small holes and solder the perpendicular wires in place.

It may seem odd soldering antennas in parallel with the PCB tracks that act as antennas, but it's important because the impedance of the PCB tracks is much higher than the thin, circular cross-section wire. So the wire antennas will dominate the response unless they are fitted in pairs as described.

Parts List

1 double-sided PCB, code 04103161, 64 x 32mm
1 20mm button cell holder, through-hole (BAT1) (Jaycar PH9238, Altronics S5056)
1 CR2032 cell (BAT1)
1 micro SPST tactile pushbutton switch (S1) (Jaycar SP0611)
1 80mm length of 30mm diameter clear heatshrink tubing (optional)
4 30mm lengths thin, stiff insulated wire (optional) (antennas for improved pick-up)

Semiconductors

2 LM339, LM239, LM2901 or LM3302 quad comparators, 3.9mm wide SOIC-14 (IC1,IC2)
1 LM4041DYM3-1.2 micropower 1.2V shunt regulator, SOT-23 (REG1)
2 BSS138 logic-level N-channel Mosfets, SOT-23 (Q1,Q2)
1 green high-brightness LED, SMD 3216/1206 (LED1)
8 red high-brightness LEDs, SMD 3216/1206 (LED2-LED9)
1 MMBD301 single or MMBD352 dual Schottky hot-carrier diode (D1)

Capacitors (all SMD 2012/0805)

1 22µF 6.3V X5R
2 100nF 50V X7R
1 220pF 50V C0G/NP0

Resistors (all 1% SMD 2012/0805)

1 10MΩ	1 1kΩ
1 15kΩ	1 220Ω
1 12kΩ	1 10Ω

Using it

Pressing S1 switches the unit on for 1-2 minutes. You can hold down S1 or press it regularly to keep the unit on while you are using it. It will then switch off by itself.

The LED bargraph indicates the voltage generated across a 220Ω load resistor, in roughly 50mV steps. Thus

The microwave oven is checked while it is in operation by moving the Microwave Leak Detector around the edge of the door and around the edge of the viewing window. If all eight LEDs in the bargraph light, then there is excessive leakage and the oven can be considered hazardous. Note: this is closer than you would normally hold it.

the segments correspond roughly to received power levels of 11μW, 45μW, 100μW, 180μW, 284μW, 410μW, 556μW and 727μW. The danger level is generally considered to be 5mW/cm^2 however we need to determine how effectively our unit picks up the radiation in order to calibrate the bar graph response.

We compared the response of the bargraph against a commercial microwave leakage detector and found that, with the 220Ω load resistor, a full scale reading (ie, all eight red LEDs lit) corresponded pretty closely to 5mW/cm^2 (the legal limit, above which it is considered hazardous) on the commercial detector. This assumes the dipole is in alignment with the field, which we determined by rotating the detector for maximum response.

Operate the oven

The oven needs to be operating in order to check for leaks but it's a bad idea to operate a microwave with nothing in it. Unless you happen to have something you want to heat anyway, the simplest solution is to fill a bowl or large mug with cold water and microwave this for a few minutes while testing, then tip the water out. Take care as it may be very hot; it's best to put in enough water to avoid it boiling during the test period.

So, if you want to check that your microwave is safe, start heating some water at full power, then switch the detector on and move it around the outside of the door – both the front face and around the sides. Also check around the edges of the window.

It's generally best to hold it such that the dipole is facing across the edge of the door. In other words, when holding it at the front of the oven, point the dipole at the centre of the door and when holding it at the sides, align the dipole so that it is pointing to the back of the oven.

Note that because the contents of the oven are normally on a rotating tray, the leakage field will change over time, as the contents will interact with the field. That means you will need to move the detector slowly and pause if you get a reading to see what it will peak at, at that location. Doing multiple sweeps is also a good idea.

Antenna distance

Generally, you should keep the antenna around 50mm from the oven as you make the sweep. But while this is the specified distance for the legal limit, the relatively long wavelength of microwave radiation (~12cm) means it's possible that the field strength could actually be higher further away from the oven, due to constructive and destructive interference. So a second sweep at a somewhat greater distance would not hurt.

If you want to use the detector to sense 2.4GHz radio signals, it's simply a matter of holding it as close to the radiating antenna as you can and rotating it until you get a response. Note that while it's quite effective at picking up WiFi router transmissions, at the low power levels generated by battery-powered WiFi devices, mobile phones and other 3G/4G devices, you may have difficulty picking up enough energy to light the LEDs. SC

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Who left that %$^^&* door open again!

We've all done it: opened the fridge or freezer door and then not closed it properly. That can cost you: the food could spoil or at the least, the refrigerator could run continuously and you'll waste a lot of electricity.

Build this Fridge Door Alarm and it will warn you whenever the door is open or ajar. Not only that, the cost to build it is far less than if you lose a fridge full of food due to spoilage.

Even the self-closing doors on modern fridges are not completely foolproof; there might be an obstruction inside the door, because an item inside the compartment has moved or fallen over or because the compartment is too full. It helps, of course, if the fridge is slightly tilted back to help the doors close by themselves.

Whatever fridge you have, our Fridge Door Alarm can be most useful. It warns when the door of the refrigerator or freezer is left open for longer than the preset time. It is great for indicating when someone is standing with the door open for too long and a real asset in warning when the door looks shut but is still partially ajar.

The fridge alarm has an LDR (light dependent resistor) which responds to ambient light. So it will respond to the fridge light which will be on even if the door is barely ajar.

And the circuit is sensitive enough so that it will all work in a freezer compartment which will normally not have an internal light (Note: recent model fridges often have white LED illumination in the freezer compartment). As long as there is some ambient light that the Fridge Alarm can detect, it will operate.

The alarm will sound if the light is present for longer than the preset period and will continue to sound until the door is closed. In practice, the preset period is set so that in normal use the alarm will not sound. It will then sound when the door is left wide open for too long or if left slightly ajar.

Note that the alarm cannot be used with display refrigerators or freezers that have glass doors – that is, unless the Fridge Alarm light sensor can be positioned so that it is covered over by the glass door frame when the door is closed.

By John Clarke

Does the light really go off?

Do you or members of your family have doubts whether the fridge light really goes off when the door is closed? Does the little man in the fridge really do his job? Or is he sitting in there

FEATURES

- Powered by a Lithium button cell
- LED brightness indicates cell condition
- Low current drain (~2.5μA)
- Two alarm sound options
- Adjustable alarm onset period (~2-180s)

shivering, trying to keep warm under the light?

This Fridge Door Alarm will finally dispel any doubts on this score. If you open the door and can hear the alarm sounding immediately, it means that the light has remained on while the door was closed. Sceptics may then say it's the fridge alarm itself that does not cease making alarm sounds and so is immediately heard when the door is opened. Well, stick the alarm in your pocket; the alarm will stop sounding!

The Fridge Door Alarm is designed to be housed in a small transparent box or more simply, a sealed plastic bag, and powered with a 3V Lithium button cell.

The Alarm is placed in the freezer or refrigerator near the door opening, so it can "see" the light from the internal lamp and from outside the compartment.

Circuit details

As can seen in the diagram of Fig.1, there is not much to the circuit; a PIC microcontroller, an LDR, piezo sounder and not much else. The 3V lithium button cell is switched via jumper link JP1. Taking up less room than a switch on the PCB, the link can be removed (and placed on one of the jumper pins – so you don't lose it!) to disable the alarm when not in use. The circuit draws only 2.5μA when lying dormant in the fridge in darkness and rising to about 0.5mA when the alarm is sounding.

Most of the time, the PIC12F675 microcontroller (IC1) is asleep and it wakes every 2.3 seconds to monitor the LDR and to power up its internal oscillator which runs at 4MHz.

Normally, IC1's GP1 output is set high (3V) and so there is no current through the 3.3MΩ resistor and the LDR. When IC1 is awake, it sets output GP1 low (0V) and the LDR forms a voltage divider in conjunction with the 3.3MΩ resistor across the 3V supply. The voltage across LDR1 is monitored at input GP3, pin 4.

In darkness, the LDR resistance is

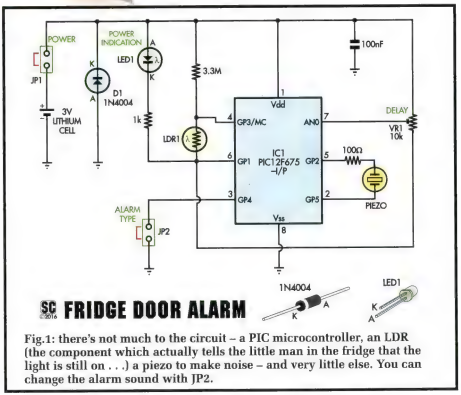


Fig.1: there's not much to the circuit – a PIC microcontroller, an LDR (the component which actually tells the little man in the fridge that the light is still on . . .) a piezo to make noise – and very little else. You can change the alarm sound with JP2.

very high (above 10MΩ) so the voltage at input GP3 is more than 2V due to the voltage divider action of the LDR and the 3.3MΩ resistor. This voltage level tells IC1 that the Fridge Alarm is in the dark (poor little fellow). If the fridge door is opened, light will cause the LDR to drop in resistance, down to around 10kΩ, which produces a low level at the GP3 input and IC1 "sees" the light. (Oh, joy!)

Diode D1 is included as a safety measure to prevent damage to IC1 if the cell holder is installed the wrong way round. If the polarity is wrong, diode D1 will shunt the reverse current. If the cell holder is installed correctly, then because of the way the CR2032 cell is made, there is no way that it can be inserted back to front. (At least that is true for the particular cell holder we used).

GP1's output is only held low for just long enough to monitor the resistance of the LDR. GP1 then returns high to save power. When GP1 is low, LED1 lights to indicate that power is applied to the circuit. The LED brightness also provides an indication of the cell voltage.

VR1 is also connected to the GP1 output again to save power. This allows one side of this trimpot to be taken low. The other end of the trimpot is connected to the 3V supply. The AN0 input monitors the voltage setting for VR1's wiper whenever GP1 is low. VR1's wiper can be set to show a voltage anywhere between 0V and the 3V supply. The voltage setting determines the delay which is adjustable from 2 to 180 seconds (three minutes).

Notes on the software

Note that the GP3 input in many projects is often configured as the MCLR input (master clear), which allows the microcontroller to have an external power-on reset. However, for our circuit we need this as a general purpose input for monitoring the LDR.

When MCLR is set up as an input, the MCLR operation is switched to an internal connection within the microcontroller so the master clear power-on-reset function is not lost. One disadvantage of using this as a general purpose input is that it is not a Schmitt trigger input.

The lack of a Schmitt trigger input at GP3 can mean that, at a particular ambient light level, the input to GP3 could be read as either a high or low input level by IC1's software. At this threshold, the Fridge Alarm could produce strange alarm sounds as IC1's software switches the alarm on and off, undecided as to the ambient light level.

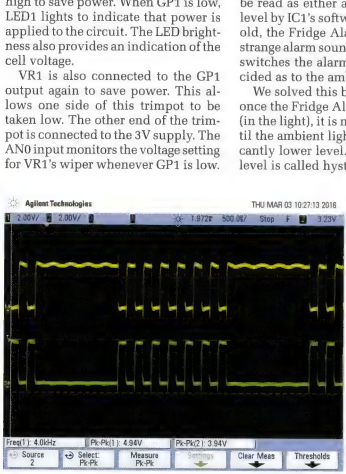
We solved this by making sure that once the Fridge Alarm is switched on (in the light), it is not switched off until the ambient light reaches a significantly lower level. This difference in level is called hysteresis.

Hysteresis is implemented by pulsing the GP1 output momentarily high when checking for a high ambient light level. High ambient light means that the LDR's resistance is low, so the GP3 input is a low voltage. The momentary high pulse level effectively raises the average GP3 voltage slightly since this pulse is filtered with the internal capacitance at the GP3 input of 50pF or less. The raised voltage means that the LDR is required to have a lower resistance (ie, have more light shining on it) to bring the GP3 voltage low enough for a low input reading by IC1.

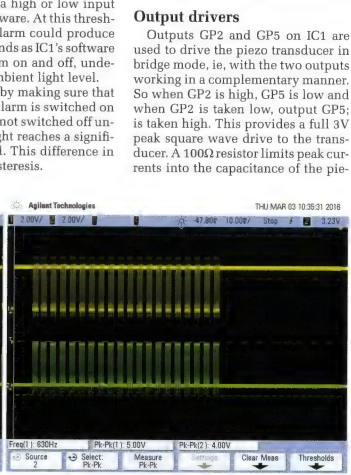
The second disadvantage of using the MCLR pin as a general purpose input is that there can be a problem when programming the microcontroller. This problem occurs when the internal oscillator is also used to run the microcontroller (which we do). We solved this problem in the software and the solution is discussed later under the "programming" subheading.

Output drivers

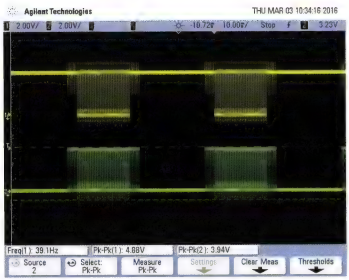
Outputs GP2 and GP5 on IC1 are used to drive the piezo transducer in bridge mode, ie, with the two outputs working in a complementary manner. So when GP2 is high, GP5 is low and when GP2 is taken low, output GP5; is taken high. This provides a full 3V peak square wave drive to the transducer. A 100Ω resistor limits peak currents into the capacitance of the pie-



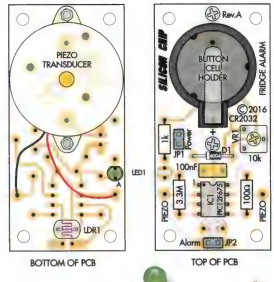
Scope1: This oscilloscope screen shows the drive signals to the piezo transducer, measured at pins 2 & 5 of the PIC microcontroller. The drive frequency is 4kHz. In effect, the total voltage across the transducer is the difference between the two out-of-phase signals, resulting in twice the voltage from pin 2 or pin 5.

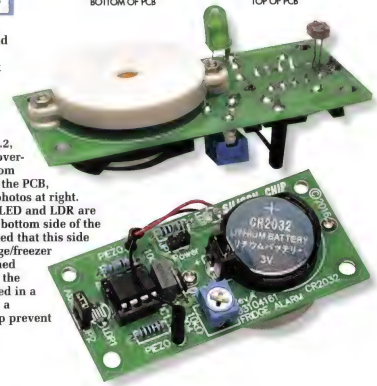


Scope2: Taken at a much slower sweep speed than Scope1, this shows the same simple chirp alarm signal, which consists of 20ms bursts of 4kHz at regular intervals. Note that the drive signal from each microcontroller output is essentially "square" but the trailing edges do have significant ringing.



Scope3: Taken at the same sweep speed as in Scope2, this is the more complex "cricket" alarm sound which we found to be more arresting (insistent, irritating, annoying – your choice). You can choose either alarm sound by having link JP2 in or out of circuit.





Above right: Fig.2, the component overlays for the bottom and top sides of the PCB, with matching photos at right. Only the piezo, LED and LDR are mounted on the bottom side of the PCB; it is intended that this side aim out the fridge/freezer door. As explained later in the text, the PCB was enclosed in a zip-loc bag with a desiccant to help prevent condensation.

zoelectric transducer at the switching of the outputs. (See oscilloscope trace and caption).

Normally, the GP4 input is set as a low output without pull-up to save on power drawn from the cell. However, whenever IC1 checks the input level, GP4 is set as an input, with an internal pull-up current source enabled. With no jumper link at JP2, the input is pulled high via this internal pull-up. When a jumper link is installed, the input is held low. This determines the alarm sound produced. Note that the GP4 input state is checked just before the alarm sounds.

The alarm can be either a short (50ms) 4kHz beep that repeats once per second (JP2 open) or a chirping cricket sound (JP2 installed). See Scope1-Scope3 for more details.

Construction

The the Fridge Alarm is constructed on a PCB coded 03102161, measuring 30 x 65mm. It is presented as a bare PCB which can be sealed inside a clear plastic bag but we have made provision for mounting it inside a small plastic case.

Fig.2 shows the PCB overlay. Begin construction by installing the three resistors, using a multimeter to check the value of each before inserting it into the PCB.

Diode D1 can now be installed, taking care to orient correctly. Fit the IC socket next, orientating its pin 1 notch as shown in Fig.2, followed by the lone 100nF capacitor (either way around) and the trimpot.

Then solder in the 2-way pin headers for JP1 and JP2, followed by the cell holder. Make sure the plus terminal is oriented toward diode D1 on the PCB.

The piezo transducer is mounted on the underside of the PCB, supported on TO-220 insulating bushes used as spacers and secured with short M2 screws and nuts. The wires can be soldered to the underside of the PCB (the positions are marked "PIEZO") or brought around to the top of the PCB. We used PC stakes for the piezo transducer wiring, on the top side, as this allows provision for heatshrink tubing over the wires and PC stakes to help prevent the wires from breaking off.

While the piezo transducer will probably come with red and black wires, the connections required are not polarised and it doesn't matter which wire is used for each "PIEZO" position.

LED1 is also mounted on the bottom side of the PCB. Make sure the longer lead of the LED (the anode) is inserted in the "A" position on the PCB. Then fit the LDR, about 10mm above the PCB surface, also on the underside. Its polarity is unimportant.

If you intend to program the PIC yourself, download 0310216A.HEX from the SILICON CHIP website and flash the PIC chip with it. See the section

Parts list – Fridge/Freezer Alarm

1 double-sided PCB coded 03102161, 30 x 65mm
1 small zip-loc plastic bag
1 packet dry silica gel desiccant
1 20mm button cell holder (Jaycar PH-9238, Altronics S 5056)
1 CR2032 Lithium cell (3V)
1 30mm diameter piezo transducer (Jaycar AB-2440, Altronics S 6140)
1 10kΩ light dependent resistor (Altronics Z 1621; Jaycar RD-3480) (LDR1)
1 DIL8 IC socket
2 M2 x 8mm screws with nuts
2 TO-220 insulating bushes
2 2-way pin headers (2.54mm pin spacing) (JP1,JP2)
2 jumper shunts
2 PC stakes
1 25mm length of 2mm diameter heatshrink tubing

Semiconductors

1 PIC12F675-I/P programmed with 0310216A.hex (IC1)
1 1N4004 diode (D1)
1 3mm green high brightness LED (LED1)

Capacitor

1 100nF 63V or 100V MKT polyester

Resistors (0.25W, 1%)

1 3.3MΩ 1 1kΩ 1 100Ω
1 10kΩ miniature horizontal trimpot (VR1)

Extra parts for mounting in box

1 UB5 Jiffy box
4 M3 x 12mm tapped spacers
4 M3 x 6mm machine screws
4 M3 x 6-9mm countersunk screws

on programming for details.

IC1 can now be plugged into its socket, with pin 1 towards the notched end, near the centre of the board.

You can now install the CR2032 cell in its holder and place the jumper link onto the 2-way header (JP1). If all is well, the LED will momentarily flash after about three seconds to indicate that power has been connected.

A brief flash of the LED also occurs when a high light level is detected. Then the Fridge Alarm will sound the alarm after the delay set by VR1. The alarm should stop when the LDR is in darkness. The delay can be adjusted from between two and 180 seconds, with two seconds when VR1's wiper is set fully anticlockwise and 180s when set fully clockwise. Mid setting provides about a 90s delay.

Note that the 2-second delay will be affected by the sampling period of the LDR that occurs every 2.3s. So the alarm may start anywhere between two and 4.3 seconds after light is detected by the LDR. As the delay is adjusted to higher periods, the variation in delay due to the sampling period becomes less significant.

Note that you can keep tabs on the lithium cell condition by observing the LED. If it flashes brightly as the fridge door is opened, then the cell is OK. As the cell discharges, the LED will become quite dim.

Programming

If you are programming the microcontroller yourself, you may be presented with a warning by the programmer stating that programming is not supported when both the MCLR is set as a general purpose input and with the internal oscillator set.

However, you will be able to program the microcontroller successfully, ignoring the warning.

That's because any problems associated with this configuration are already solved by a software solution. Read on if you want more details.

As mentioned, we set MCLR as a general purpose input and utilise the internal oscillator within IC1. This can present problems for a programmer during the process of verifying the software code after programming.

The problem lies in the fact that as soon as the microcontroller is programmed, it will begin executing its program. A typical program initially sets up the microcontroller with the general purpose (GP) lines set as inputs or outputs (I/O).

This conflicts with the programmer needing to use the clock and data programming I/O lines for program verification.

This problem does not happen if the MCLR pin is set as the external MCLR input because the programmer then has control over the microcontroller, stopping it from executing the programmed code.

Note also that in order to run the code, the microcontroller needs to operate from the internal oscillator instead of an external crystal, RC oscillator or clock signal.

The programming problem is solved in the software provided by including a three second delay at the start of the program. This delay is before the I/O lines are set as inputs or outputs.

The I/O lines therefore remain as high impedance inputs while the programmer verifies the internally programmed code using the clock and data programming lines.

A warning from the programmer will still be issued but the microcontroller can be programmed successfully and correctly verified by the programmer.

Note that the PIC12F675 also needs special programming due to the fact that it has an oscillator calibration value (OSCAL) that is held within the PIC's memory.

This calibration value is individually programmed into each PIC by the manufacturer and provides a value that allows the PIC to run at an accurate 4MHz rate.

This value must be read before erasure and programming so that it can be included with the rest of the code during programming.

If this procedure is not done, then the oscillator could be off frequency and that will have an effect on the Fridge Alarm sound.

Most PIC programmers will automatically cater for this OSCAL value, but it is worthwhile checking if your programmer correctly handles this. Finally, be aware that the PIC12F675 requires a 5V supply for programming, even though it happily runs at 3V in the circuit.

In use

Condensation will always be a problem in a fridge or freezer. To help overcome this, once we confirmed it was working correctly, we sealed the unit inside a "zip-loc" type plastic bag and at the same time, included a bag of desiccant (silica gel) which will help absorb moisture.

You should be able to find some silica gel – we're always throwing it away as it comes packed with a lot of equipment, photo gear, etc, where moisture can be a problem.

Because of the ultra-low current drain, battery life should be not much less than cell's shelf-life. SC

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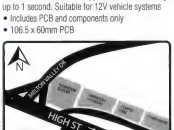

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Sensor	1.3" CMOS	1.3" CMOS	1.3" CMOS	1.3" CMOS
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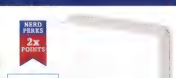

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2 x Reed Switch
1 x Bellbox
2 x 50m 6 core cable
1 x 12V 1.2Ah backup battery
1 x Internal siren

NOW **$349**
SAVE $50

DIY

Keypad Shed Alarm

LA-5214

Consisting of a keypad and single reed switch for a door or window and 5m of cable for easy DIY installation. Use as an instant alarm, with an entry delay, or as a door chime to announce entry. Uses a single 9V battery (not included).
162(H) x 85(W) x 32(D)mm.

$9.95

Standalone Motion Activated Alarm

LA-5217

Easy to install PIR sensor with wide 120° coverage. Features loud 120dB alarm and delay function. Includes remote.

$34.95

ALARM ACCESSORIES

$1.95

NC Reed Switch

IDEAL FOR BURGLAR ALARMS SM-1002

- Total length: 44mm
- Contact rating: 10W
- Switching volatge: 200VDC (max)
- Switching current: 0.5A (max)
- Carrying current: 1.0A (max)

LA-5072

FROM **$4.95**

Combos Magnet / Reed Switches

These are used to secure an alarm circuit on a door or window. Sold as a pair, one has a magnet inside, the other a reed switch. They have powerful magnets, with self adhesive or screw mount. Screw terminating.

NORMALLY CLOSED (NC) LA-5072 **$4.95**

NORMALLY OPEN (NO) & NORMALLY CLOSED (NC), BOTH IN ONE UNIT
LA-5070 **$5.95**

Blue Siren / Strobe LA-5306

Make an emergency situation known instantly with this siren and LED strobe combo. Extremely loud 120dB output, ideal for alarm systems. 12V.

$16.95

Multi-Sensor PIR Detectors

Reliable and effective PIR detectors for added peace of mind. Easy to install, excellent false alarm suppression. The quad unit offers higher levels of detection.

DUAL PIR
LA-5044 **$34.95**

QUAD PIR
LA-5046 **$39.95**

LA-5044

FROM **$34.95**

DOUBLE POINTS ON THESE ESSENTIALS TO COMPLETE YOUR ALARM SYSTEMS

NERD PERKS 2x POINTS

$9.95

Indoor Alarm Piezo Screamer LA-5256

This unit is very popular for indoor use with house alarms as it emits a loud piercing sound making it near impossible to stay inside. Dustproof and waterproof. 100dB output.

NERD PERKS 2x POINTS

$19.95 ea

Mini Size LED Strobes

Suitable for security, alarm or emergency use. Suitable for outdoor alarm applications. Mounts with 2 x 5mm bolts.

- 12VDC
- 70(Dia) x45(h)mmH)mm.

BLUE LA-5326
RED LA-5327
AMBER LA-5328

NERD PERKS 2x POINTS

$24.95

Alarm Relay Module LA-5558

Enables you to supply an external power source so as not to overload the power supply. Can also switch high currents to multiple sirens and strobe lights in large alarm installations. 15A rated.

NERD PERKS 2x POINTS

$34.95

12V Sealed Lead Acid Battery

SB-2486

Long life and maintenance-free. Ideal for standby and emergency applications to keep your alarm systems on the go.

- 7.2Ah
- 720MA Charge current for 10-14 hours
- 150(L) x 65(D) x 93(H)mm

25¢/m

Bell Wire

WB-1700

Ideal for doorbells, intercoms, or anywhere where a really thin tig 8 cable is required.

- 7/0.10mm x 2.
- Roll length 100 Metres
- Sold per metre

NERD PERKS 2x POINTS

FROM **80¢/m**

Alarm Cables

4 CORE - 7X0.16
WB-1590 **80c/M**

6 CORE - 7/0.2 X 6
WB-1598 **$1.95/M**

NERD PERKS 2x POINTS

$9.95

Cable Tie Tidy Kit

HP-1198

Keep your cabling neat and tidy. Consists of. 30 x 120mm cable ties, 20 x 120mm reusable cable ties, 10 x self adhesive cable tie mounts, 20 x saddle type cable tie mounts.

NERD PERKS 2x POINTS

$19.95

6P/8P Modular Crimp Tool TH-1935

This tool will crimp 6P2C, 6P4C-RJ11, 6P6C-RJ12 and 8P-RJ45 plugs. Also cuts and strips the cable.

ss Control
PERKS BUNDLE
UED OVER $178

ide your conventional door locks to keyless electronic access, you can now create your o frequency device without breaking your bank.

ARROW ELECTRIC DOOR STRIKE
grade your conventional door locks to keyless ntry electronic access. LA-5077 **$44.95**

DIGITAL KEYPAD WITH RFID ACCESS
Durable, weatherproof and vandal resistant. Up to 2000 users 12VDC. LA-5353 **$129**

WAFER CARD ZZ-8952 **$4.95**

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BUY ALL FOR $148
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Standard Door Strike
LA-5076
It converts a conventional lock- set to an electronic access-controlled locking system. Benefits include higher security, and user convenience without needing to use a key.
- 12VDC
- 450mA (on striking)

$49.95

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SOLAR POWERED SECURITY

$44.95

All-in-One Security Spotlight
SL-3238
Solar rechargeable with PIR for day/night use. Adjustable spotlight head to shine the light where you need it most. Easy to install. Bright 250 lumens.

Solar Powered Wireless IR Annunciator Kit LA-5176
INCLUDES:

WIRELESS IR DETECTOR
- 4x AAA rechargeable batteries
- Up to 100m transmission range
- 2.6m detector range

ANNUNCIATOR
- Requires 4x 1.5V D size alkaline battery
- 433.92MHz transmission frequency

SOLAR PANEL
- 173 (L) x 123(W) x 14(D)mm

$119

SIGN-UP IN-STORE OR ONLINE TODAY BY VISITING: www.jaycar.com.au/nerdperks

PROTECT YOUR WORK AREA - DOUBLE POINTS FOR NERD PERKS CARD HOLDERS

3-in-1 Stud Detector
WITH LASER LEVEL
QP-2268
Beeps when you're over the stud & shows the proximity via the large LCD. Displays a target graphic when you're spot on. Also features live wire (voltage) detection.
- 180° pivoting laser plane with level and plumb vials
- Powered by 9V Battery (included)
- 180(H) x 67(W) x 38(D)mm

$64.95

$99.95

Network Cable Tracer
XC-5083
This tone generator is a highly practical network installation and troubleshooting tool which features a single/multi tone signal, test leads and a 4 conductor modular cable.Require 9V battery. Supplied in a handy protective zip up vinyl case.

400A AC/DC Clampmeter
QM-1563
Easy one-hand operation make this meter perfect for the working installer or tradesman. This is a quality, intermediate-level clampmeter with more than useful current ranges up to 400 amps AC and DC.

$129

$309

Inspection Camera
WITH 3.5" DETACHABLE WIRELESS LCD
QC-8712
View and record video and pictures in confined and dark locations. The head and flexible boom are IP67-rated for use in harsh environments. 1m flexible boom. 2.4GHz. Hook, mirror, magnet & 2GB microSD card included.

24.95

ge Case
dy up your workspace. 4 trays, each nt has a 233 x 122 x 32mm. ents storage boxes fro small items. generous 265 x 160 x 65 space. 0(H) x 150(D)mm

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TS-1580
Removes dangerous solder fumes from the work area. It incorporates a ball bearing high volume fan to maximise airflow upwards at the rear of the unit to aid in safe dispersion of fumes. ESD safe.
- 240(H) x 200(W) x 170(D)

Spare filter sold separately TS - 1581 $9.95

IP67 True RMS Autoranging Cat IV DMM QM-1549
An excellent true RMS multimeter that features a large, easily read display and carries an IP67 environmental rating
- Auto power-off
- Data hold & relative function

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FROM $139

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Line Interactive UPS
Protect your valuable computer system and critical data from black-outs and power surges. USB interface cables included in both.

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DUINOTECH AND ARDUINO® ESSENTIALS

ARDUINO® PROJECT FOR NERD PERKS CARD HOLDERS

SEE STEP-BY-STEP
www.jaycar.com.au/diy

NERD PERKS BUNDLE Build A Secret Knock Detector

VALUED OVER $61*

DUINOTECH NANO BOARD - ARDUINO® COMPATIBLE XC-4414 **$29.95**
ARDUINO® COMPATIBLE MINI BREADBOARD WITH 170 TIE POINTS PB-8817 **$4.95**
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PLUG TO SOCKET JUMPER LEADS 150MM - 40 PIECES WC-6028 **$5.95**
OR
PLUG TO PLUG JUMPER LEADS 150MM - 40 PIECE WC-6024 **$5.95**
AND
SOCKET TO SOCKET JUMPER LEADS 150MM - 40 PIECE WC-6026 **$5.95**
** If WC-6024 & WC-6026 option selected*

DIY

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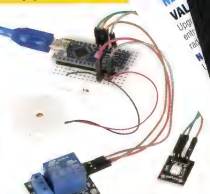

Completed project.

PCDUINO

$149

PcDuino V3.0 with Wi-Fi XC-4350

The latest version of the pcDuino single-board-computer. This is the full size pcDuino board and includes the LVDS connector to connect an LCD touchscreen. Ideally suited for creating a wireless media centre.

- Built in Wi-Fi capability
- Supported digital audio via I2C.

Duinotech Experiment Kits

The entry point for learning and experimenting with Arduino®. These experimental learning kits contains all the tools to get you up and running including a duinotech board, a breadboard, jumper wires and a plethora of peripherals enclosed in a durable plastic organiser.

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MEGA KIT (OVER 30 PIECES) XC-4286 **$109**

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Learn about the exciting new world of Arduino® with these easy to build projects. From flashing an LED to moving things with a servo. Complete with instructions and a supporting web page and software examples.

- No soldering required

$109

ARDUINO® ESSENTIALS

$4.20

Stackable Header Set HM-3207

The perfect accessory to the ProtoShields and vero type boards when connecting to your Arduino® compatible project.

- 1 x 10-pin
- 2 x 8-pin
- 1 x 6-pin
- 1 x 2x3-pin (for ICSP)

$14.95

Jumper Lead Assortment Kit - 90 Pieces WC-6029

Jumper lead set for use in Arduino® projects, school experiments and other hobbyist activities. A kit of 90 pieces measuring 220mm in length and 2mm in width.

PB-8814

FROM $12.95

Solderless Breadboards

Three sizes of breadboards to suit all your project needs.

300 TERMINAL HOLES PB-8832 **$12.95**
640 TERMINAL HOLES* PB-8814 **$19.95**
1280 TERMINAL HOLES PB-8816 **$43.95**
**Limited stock, not available online*

Solderless Breadboards

WITH POWER SUPPLY PB-8819

Ideal for circuit board prototyping and Arduino® projects. The power module can be powered from either a 12V plug pack or from 5V using the micro USB socket with a switchable output between 3V and 5V DC.

- 1 x Solderless Breadboard with 830 Points
- 1 x Power Supply Module
- 64 mixed jumper wires of different lengths and colours

$19.95

$8.95

Arduino® Compatible Mini Prototype Board Shield XC-4480

Drop this shield onto your Arduino® for prototyping small circuits. Solder-pads and a small breadboard is included which can be stuck to the top of the shield with the included tape.

- Fully compatible with Arduino®, Duinotech LEONARDO, Duinotech Classic

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Resistor Pack 300-Pieces

RR-0680

This assorted pack contains 5 of virtually each value from 10Ω to 1MΩ.

- 0.5W 1% mini size metal film

See website for full contents.

$29.95

LED Pack 100-Pieces

ZD-1694

This assorted pack contains 3mm and 5mm LEDs of mixed colours. Even includes 10 x 5mm mounting hardware FREE! *See website for full contents.*

- Red, green, yellow, orange LEDs

$34.95

Light Duty Hook-up Wire Pack - 8

WH-3009

Quality tinned hor
included, each

- 25m on ea

To order phon

NERD PERKS
SPECIAL
$3.95
SAVE $4

Magnetic Reed Switch Module
XC-4476 **RRP $7.95**

A simple to use reed switch module, output will turn wherever the reed switch is in proximity to a magnetic field. useful for door security.

- Operating voltage 3-5VDC
- Digital output
- 16mA comparator output capacity
- 37(L) x 15(W) x 23(H)mm

Limited stock

NERD PERKS
SPECIAL
$9.95
SAVE $10

Arduino® Compatible Temperature Sensor Module
XC-4538 **RRP $19.95**

This versatile 1-wire bus temperature sensor module features 0.5°C accuracy and fast response, and is easy to connect up for all projects.

- Detects -55°C to +125 °C
- 20(W) x 15(L) x 5(H)mm

NERD PERKS
SPECIAL
$14.95
SAVE $5

8 x 8 Dot Matrix Driver Module
XC-4532 **RRP $19.95**

Driven by shift registers it requires only three inputs, plus power.

- Operating Voltage: 5VDC
- Daisy-chainable.
- Chipset: 74HC595
- 72(L) x 69(W) x 12(H)mm

NERD PERKS
SPECIAL
$14.95
SAVE $5

Arduino® Compatible Fan
WITH PROPELLER MODULE
XC-4534 **RRP $19.95**

It allows you to develop your own speed control project. A high efficiency propeller can easily blow a light flame at a distance of 20cm.

- 75mm diameter propeller
- 5VDC working voltage
- 29(L) x 22(W) x 10(H)mm

$7.95

Ultrasonic Sensor Module XC-4442

The popular HC-SR04 ultrasonic distance module provides an easy way for your DuinoTECH to measure distances up to 4.5m.

- Uses just two digital pins
- Operating Voltage: 5V
- 45(W) x 20(D) x 13(H)mm

$9.95

Arduino® Compatible 5V Stepper Motor XC-4458

A small, versatile motor and driver set that can be used with any Arduino® or compatible boards via jumper leads. Four-phase LED indicates the status of the stepper motor.

- 35(L) x 32(W) x 10(H)mm

$9.95

Arduino® Compatible Obstacle Avoidance Module XC-4524

An inexpensive solution for an IR obstacle avoidance sensor, perfect for robotic projects with easy interface with Arduino® & compatible boards.

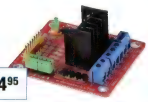
- Adjustable frequency and intensity
- 4 pin header
- 42(L) x 27(W) x 18(H)mm

$14.95

ATmega328P Microcontroller
ZZ-8726

An Atmel AVR ATmega328P microcontroller to build customised Arduino® compatible projects. Includes 16MHz crystal oscillator.

- Pre-installed Arduino® Uno bootloader



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Arduino® Compatible Stepper Motor Controller Module XC-4492

Allows full control of two DC Motors or one stepper-motor. Suited to drive two-motor robot kits such as our KR-3130 or KR-3132. An on-board 5V regulator can be used to power your project.

- 3-30VDC motor voltage
- Requires six digital inputs
- 69(W) x 56(D) x 36(H)mm

$19.95

Arduino® Compatible 2 X 16 LCD Controller Module XC-4454

Comes with a built-in 16 character by 2 line LCD display with backlight, this six push button keypad allows you to create a user friendly interface for your project

- LED Backlight
- 4 Bit Arduino LCD Library
- 80(W) x 58(D) x 20(H)mm

$66.95

OLED Display Module
FOR ARDUINO® XC-4270

Light up your display needs with this high resolution, full colour OLED display module! Perfect for graphics, gauges, graphs, even make your own video game or interactive display.

- 16,384 full colour RGB pixels in a 128 x 128 format
- 44(W) x 36(H) x 5(D)mm

$149

GPRS/GSM Shield
FOR ARDUINO® XC-4221

It contains all the features of your average mobile phone. Once you add your own SIM-Card, you can make phone calls, send SMSs, and even connect to the internet! Two 3.5mm audio jacks connect a speaker and microphone for voice calls. A SIM-card holder is located on the underside of the board (SIM-Card not included).

- 86(W) x 57(D) x 18(H)mm

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NS-3013

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2x POINTS

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NERD PERKS
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240V Soldering Irons

Ideal for the hobbyist and handy person. Has a stainless steel barrel and orange cool grip impact resistant handle. Fully electrically safety approved.

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TS-1555

$17.95

20/130W Turbo Soldering Iron
TS-1554

This turbo soldering iron allows you to switch from 20W to 130W with ease. Weller-style removable barrel, plated tip and ceramic element.

SPARE TIPS AVAILABLE:

0.5MM CONICAL TIP TS-1555 **$4.95**
1MM CONICAL TIP TS-1556 **$4.95**
2MM CHISEL TS-1557 **$4.95**

$159

NERD PERKS
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Portasol Super Pro Gas Soldering Tool Kit TS-1328

Your companion for urgent soldering needs. Includes a quality Portasol® Super Pro iron with various tips, quality storage case and cleaning sponge/tray.

See terms & conditions on page 8.

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Terminate large power cables with no need for crimping. Each has a grub screw for attaching to the power cable. Gold plated for a professional look.

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0GA - 4GA ADAPTOR HC-4069
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50% OFF

CMOS Dome Camera

WITH IR QC-8635 **WAS $64.95**

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- 380TV lines
- 6.0mm lens
- 18m cable

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RED / BLACK 500A

HM-3087 **WAS $14.95**

Protect exposed positive/negative battery connections from dust, grime etc. Suitable for automotive, marine, or industrial use.

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- 66(L) x 42(W) x 25(H)

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30pc Electronic Tool Kit

TD-2107 **WAS $29.95**

An electronic tool kit with all the essentials - cutters, pliers, screwdrivers etc. Ideal for servicing the computer.
Limited stock, not available online

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Motion Activated Tracking Spotlight

SL-2705 **WAS $119**

Motion is tracked via the two front facing PIR sensors. The light will pan left to right to follow a persons movement. 4 x 3W LEDs to produce 500 lumens of light. Use the remote control to adjust the brightness and horizontal direction of the light.

- Rotational range of light: 240°

NOW $109
SAVE $10

720p HD P2P Wi-Fi Camera

QC-3840 **WAS $159**

Provides a true colour experience, and can be easily configured to automatically email and/or upload images to an FTP server.

- Viewing Angle: 60°
- Infrared light: 8 IR LEDs with up to 15m night visibility
- Resolution: 1280 x 720 (720p), 640X480 (VGA), 320X240 (QVGA)
- Supports: iPhone®, iPad®, Android® Smartphone

NOW $139
SAVE $20

HID Spot/Search Light

WITH REMOTE CONTROLLED PAN/TILT

ST-3377 **WAS $169**

- 12VDC
- 3200 lumens
- Effective Range: 1000m+
- 230 (H) x 185 (W) x 150 (D)mm

NOW $139
SAVE $30

2.5 LCD Video Door Phone

WITH RFID ACCESS QC-3622 **WAS $249**

This high quality unit consists of an outdoor camera with door bell/entry button as well as RFID access.

- includes power supply
- Outdoor camera dimensions: 142(H) x 92(W) x 40(D)mm
- Monitor dimensions: 180(H) x 79(W) x 33(D)mm.

ALSO AVAILABLE

SPARE RFID TAG QC-3623 **WAS $9.95 NOW $7.95 SAVE $2**

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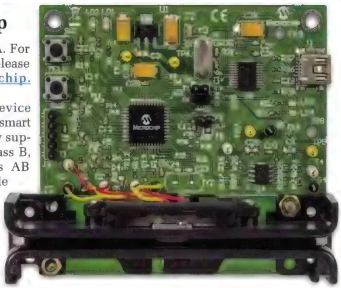
PRODUCT SHOWCASE

Point-Of-Sale Solutions from Microchip



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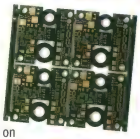

PCBCart recently sent out a questionnaire to PCB designers and electronics manufacturers on what to look for in a PCB service supplier. The collated results were:

Manufacturing Capabilities

Pre-check manufacturers' capabilities on PCB fabrication; make sure they fulfill your design requirements on board materials, specifications, and lead time.

Quality-guaranteed Production

Choose suppliers which have advanced manufacturing facilities and follow the industry's highest standards for quality and delivery. One of the most straightforward ways would be to ask for their certifications.

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SERVICEMAN'S LOG

Odyssey Stratos amplifier voltage conversion

Staff member Nicholas Vinen loves big amplifiers. Well, big anything actually – big speakers, big engines, big cars, big monitors, big . . . you name it! Many years ago, he bought a big amplifier in the USA but then had to convert it to operate from 230VAC for use in Australia.

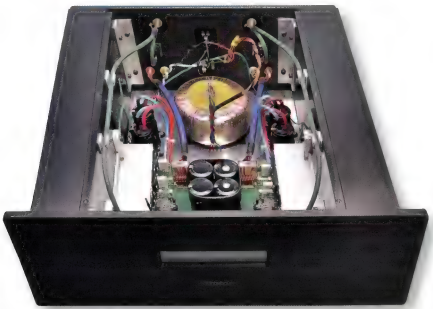
Items Covered This Month

- Converting an Odyssey Stratos amplifier from 110VAC to 230VAC.
- Faulty home lighting system
- Dave's faulty air-compressor
- Digitor T-1333 sound system

The Odyssey Stratos is an impressively large stereo amplifier, with a power output of 150W RMS per channel. I bought this beast around the year 2000 while living in the USA. It was during those heady "Dot Com Boom" days when venture capitalists were just about giving away free money to anybody with a business plan that included the word "Internet" in it. The company I worked for was bought by another company which was then bought by another company which wasn't quite sure what to do with my division. In the end, I was sent home and I brought the Stratos with me.

These amplifiers are still being sold today – see www.odysseyaudio.com/products-stratos-stereo.html I didn't know much about amplifiers when I bought it (how things change) but the reviews were good, the "specs" were impressive and it came with a 20-year warranty. I also liked the idea of the whole aluminium chassis being the heatsink, so cooling wouldn't be a problem no matter how hard I drove it.

Anyway, having brought the Stratos home, I had to figure out how to power it. It's a 115VAC model and for years I used a 2kW step-down transformer. But this arrangement had a few drawbacks. First, the step-down transformer was quite large, as was the amplifier, and the whole shebang took up a lot of space. Second, it was inefficient and consumed a lot of power at idle, meaning I had to turn it on and off at the wall, which I found inconvenient. And third, if I wanted to transport the amplifier, I had to cart the transformer around too.



The Odyssey Stratos stereo amplifier is quite a large beast and is capable of pumping out 150W RMS per channel. Converting it from 115VAC to 230VAC operation proved to be a bit of a challenge.

Before bringing it home I spoke to the bloke I bought it from (at the factory) and he told me that they sold 220VAC versions of the same amplifier for the European market and there were only a few slight differences. So I knew it would be possible to change it to run from 230VAC but, at the time, I didn't press him for details.

Having put up with the step-down transformer for so long, I recently thought that I'd open it up and see how hard it would be to convert it to 230VAC operation. As expected, the mains transformer (a 400VA toroid) has two primary windings and these are connected in parallel for 115VAC operation. This meant that I could change the transformer configuration so that the primaries were connected in series for 230VAC operation. And thanks to the IEC mains input socket, I could easily replace the mains cord after doing this.

Before starting, I checked that the socket and mains switch were both rated for 250VAC and this was indeed the case. The mains switch contained a neon lamp with an in-built resistor but I figured since it was 250VAC rated, this wouldn't need any modification. But how should I reconfigure the transformer? I didn't want to reconnect it with the wrong phasing and burn it out.

The problem was that I didn't know

which colour wire was which and with the windings connected in parallel, there was no obvious way to measure it and find out. After some thought, I realised that if I disconnected one of the primary wires going to Neutral (at the IEC socket) and one going to Active (at the switch), then as long as they weren't from the same winding, connecting these two together would give the desired result.

The primary wires emerge from the transformer in this order: brown, black, red, orange and green/yellow. Green/yellow is presumably for an earthed screen and I guessed that brown/black and red/orange were the two winding pairs, with brown and orange being connected to Neutral and red and black to Active. Tentatively, I clipped off the black and orange wires as it was difficult to de-solder them (there were multiple wires looped through and then soldered to each terminal).

As well as the outer insulation jacket, the wires were enamelled so I placed a plastic tray under them and scraped away the enamel insulation from the ends. I then checked the continuity of the windings. The resistance of the brown/black and red/orange pairs was about 1.5Ω, confirming my suspicion that these were the two primaries.

The odd thing was that I was still getting a continuity reading between the two primary pairs which should have now been disconnected. The resistance was much higher though, at around 200Ω. However, I was pretty confident that I had the right wires so I soldered the orange and black wires together and insulated the joint with yellow heatshrink tubing.

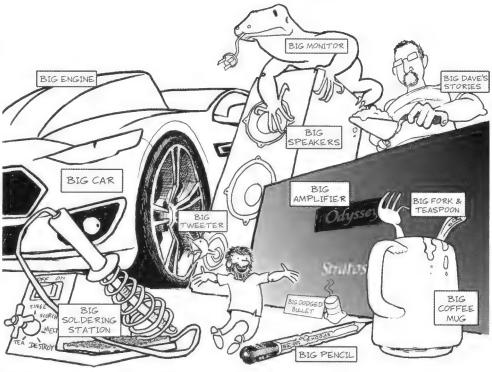
I was still puzzled as to why I was getting such a low reading between what should have been disconnected pairs though and decided to investigate further. And then it hit me. The front of the amplifier has a glass panel with the Odyssey logo sandblasted into it. This logo is lit by a pair of incandescent lamps. Duh, the black and white pair of wires I noticed earlier running from the mains sockets must be to supply these lamps with 115VAC!

Had I plugged it into 230VAC, the lamps would have immediately blown and I'd have had buckley's chance of finding exact replacements locally. Anyway, I dodged that bullet and since there were two lamps, I reasoned that I could connect them in series and they would happily run off 230VAC, at least until one eventually blew, when they would both go out.

This wasn't difficult to arrange. All I had to do was clip the white wire going into the first lamp and the black wire running between the two, strip the ends back and connect the incoming white wire to the black wire from the second lamp. The two would then be in series. I did this, then insulated the solder joint and the two wire ends which now connected to nothing.

Finally, I changed the mains fuse from 6.3A to 3.15A 250VAC, stood back and powered it up. You beauty, it worked! It did blow the fuse the second time I turned it on though, obviously due to the transformer inrush current. Replacing the fuse with a 3A slow-blow fuse fixed that problem.

At last, I could say goodbye to that clunky step-down transformer.



NICHOLAS LOVES BIG AMPLIFIERS ~ WELL, **BIG** ANYTHING ACTUALLY

Home lighting system

Sometimes, a puzzling fault can have a very simple explanation as G. B. of Ararat, Victoria discovered when he was recently called out to service a large diesel-powered generator. Here's what happened . . .

Many years ago (more than I care to remember, in fact), I learnt the art of servicing Cooper engines from my father. Very popular from the 1930s though to the 1950s, these engines could be found on practically every farm in Victoria that hadn't yet been connected to the SEC, as the electricity grid was then known.

Basically, they were single-cylinder petrol engines that were used to drive shearing machines and 32V home lighting plants. And it was not uncommon for some farms to have several such machines.

One day back then, we got a call from the father of a lad I went to school with. "Rodney says you're pretty smart. Will you come and see if you can fix our lighting plant? It won't run properly and every electrician we can find hasn't been able to fix it." I should have woken up then: electricians don't fix engines and I don't fix electrical problems.

I know better now but then I said "OK" and collected the tools to give the engine the usual required valve grind. A faulty valve seat was about the only thing that could make one of those things hard to start.

The trouble was I either hadn't listened or hadn't been told the full story. I arrived at the farm and was pointed to the engine shed with the comment "It starts OK but won't keep going." Well, this was going to be easy, I thought. If an engine has fuel, air, compression, ignition and exhaust, it must run.

The first shock came as I walked into the engine shed. Instead of a Cooper engine happily turning a generator to charge a bank of 32V batteries, I was faced with a huge Lister diesel rigged as a "Startamatic" plant.

The principle of the Startamatic was that if somebody turned on a

One thing leads to another with DIY

It's marvellous how one thing can lead to another. All I wanted to do was paint a room but I ended up stripping down an air-compressor.

By Dave Thompson

One of the tasks I undertook during my recent workshop clean-out was to improve accessibility to my air-compressor. Until then, the compressor had been sitting beneath my drill press-bench. Whenever I needed it, I had to drag the thing into the middle of the workshop floor and clear away all the dust and swarf from it before rolling out its retractable hose.

For the amount of times I used the compressor, it was a tolerable work-around. However, as I was moving stuff around during the clean-up, I finally decided to find a better position for it.

Recently, I took delivery of a heavy-duty transformer-winding machine and it came with its own solid worktable that fitted perfectly into a corner of my workshop. There was an area under the table, beside the treadle-operated clutch, that begged to have something stored in it and I soon discovered that my air-compressor fitted into that space as if it was specifically designed for it. I then mounted the retractable air-hose reel onto one of the 10 x 75mm legs of the table and from there I can now roll the hose out anywhere into the workshop or into an adjacent garage.

That's the way things remained until I needed the compressor recently. Nina and I had decided to redo one of our bedrooms because the previous owner of our house had done a slap-up job of throwing up some wallpaper without properly preparing the wall. As a result, several patches of unsightly and unhealthy-looking mildew had begun peeking through the wall covering.

Stripping away the old paper fell to Nina. The theory was that once she'd removed it all, we'd throw an anti-mildew undercoat onto the now-bare wall, followed by a couple of top-coats to finish it. But, as we all know, DIY doesn't always follow one's nicely laid-out plans.

First, we discovered that instead of standard plasterboard (or drywall), whoever built the house in 1959 had decided to go for fibrous plaster. It's an absolute @!%$# to work with! The molecule-thin top-coat of plaster on fibrous plasterboard breaks away with just the slightest provocation to reveal the true make-up of the board, which appears to be plaster mixed with horse-hair bristles.

This meant that wherever the wallpaper had been stuck on with a bit more glue than usual, the plaster had pulled away and there were now decent-sized patches of rough, hairy bristles showing through.

Being a serviceman, I did what anyone else in my position would do and retrieved the biggest random-orbital sander I could find in my workshop. However, all the sander did was remove more of the plaster holding the bristles together. As a result, the patch I was working on grew slowly larger until I had to chuck in the towel and admit that that particular strategy wasn't helping.

I then decided that what I needed to do was trim the hairs off the wall altogether and since there weren't that many patches, I could simply use a sharp blade to "shave" the walls. After that, a bit of filler added here and there would be all I'd have to do to prep the walls for painting.

Except, of course, it didn't work out like that (but you probably knew that already). It turns out that the fibres used in fibrous plaster are made of the same stuff used to sew Superman's cape and underpants together. Nothing short of a freshly-stropped straight razor would cut them and then only by direct perpendicular pressure from blade to bristle. This also left more marks on the wall.

~I NEEDED TO TO SHAVE THE HAIRS OFF THE WALL

At the rate I could trim hairs back, it would take until Christmas 2019 before I'd done half the room so I called in my builder friend Dave for some advice. He told me that the best solution was to put what he called a "skim coat" of plaster on the wall. Once we had that, we could then prime, paint and be done with it

Anyway, as usual I digress. One of the other reasons I stopped my initial sanding was that the dust being generated choked everything. While the sander itself has a dust-extraction nozzle, which I married up to a back-pack-style vacuum cleaner, even this set-up couldn't cope with the sheer amount and texture of the plaster dust. It was as fine as talcum powder and it spread out everywhere. What's more, the vacuum cleaner's bag choked after just a few minutes, rendering it useless.

So what's all this got to do with my air-compressor? Well, another problem I encountered was that the sander got so hot I couldn't hold onto it and that was only after 10 minute's sanding. So it was out to the workshop to clean those tools and filters with my trusty air-compressor, only to have it run out of puff after a just few seconds of cleaning.

Thinking that I must have a loose power lead, I checked the connection but that seemed to be in order. I then tried switching the compressor off and on again, only for it to start and then immediately stop. Just what I needed – a faulty air-compressor.

Mildly annoyed because my plans for that afternoon hadn't included stripping down the air-compressor, I pulled it out from its new hidey-hole and lifted it onto the bench. This machine is one of Dad's old compressors and isn't one of those cheap units that are available these days. On the contrary, it's a high-quality Italian-made unit with impressive specifications for such a small unit.

Usually, with a compressor, it's the seals and gaskets that wear out and you simply replace them to get things huffing and puffing again. As a result, I stripped it down with the aim of doing just that. The head of the pump was held on by four long bolts and they were soon out and the head lifted clear. This revealed what looked like stainless-steel spring valves, all embedded into the head itself.

Inside the pump body was a piston and con-rod assembly. However, instead of a gudgeon pin joining the two parts together, the piston and con-rod were a single forged item, with a hard-rubber and plastic ring arrangement built into the crown of the piston. An electric motor ran the crankshaft directly, driving the piston up and down in the aluminium (yes, aluminium!) sleeved bore.

Due to the very short stroke, the crown of the piston simply pivoted from side to side as it moved up and down inside the bore, relying on the seal to make and keep contact with the bore all through the stroke. It was a nice, simple system but one that's prone to wearing out pretty quickly I'd imagine.

I was going to need a new piston and bore, plus a new head assembly, and that sounded expensive to me. There was a service sticker on the compressor so I dialled the number only to discover that it was now disconnected. I then hit the Internet and discovered that the company in question had shut its doors in 1997, after more than 50 years operation.

I then found the manufacturer's website and sent off an email asking if they had an NZ agent. A week later, I received a response which recommended I contact a Hamilton company, which I did but they dealt mainly in $10,000 plus air systems and weren't overly interested in one small compressor.

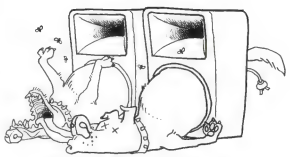
After a bit more searching, I found another company who had the compressor manufacturer's logo on their website, so I emailed them and received a prompt response asking me what model I had. I'd included all that detail in the first email, so they obviously hadn't read it carefully. I repeated what I'd previously told them and after some email to-and-fro, they finally sent me some exploded-view diagrams of the pump unit.

I went through them and supplied the relevant part numbers plus photos and details of my worn-out parts as well. That was weeks ago and despite sending off two emails in the interim, I've heard nothing.

In the meantime, I still needed an air-compressor and so I ended up shelling out for a budget one which did the job nicely. If I ever hear back from the parts company, I expect that the replacement parts for my Italian job will cost far more than this new compressor but I'm hoping I'll be pleasantly surprised. I'll let you know what happens.

PA speakers

Last week, a chap brought in two rather large, powered PA speakers, complaining they had blown woofers. They'd been using the speakers at a function and according to the owner, they hadn't been playing them "that loudly" when suddenly the sound level dropped dramatically and became "tinny" and "screechy".



After connecting a signal injector to each amplifier's input, I quickly confirmed that the two big 15-inch woofers had indeed stopped working. A bit of research then revealed that these speakers are supposed to be able to cope with 150W RMS and I soon found suitable replacements on an online auction site.

The owner subsequently purchased the required units and brought them around for me to fit. They were about twice the weight of the old ones and the voice coils half as big again. Given the difference, I'd estimate the original speakers to be 100W maximum, though the stickers on the plastic-moulded speaker cases claimed they delivered up to 800W!

In my opinion, they might get to 800W peak music power output (PMPO) but certainly not 800W RMS.

Swapping the speakers over was a doddle; I simply removed the 10 large screws holding each woofer in place, pulled the old speakers out and slipped the new ones in. Push-on terminals had been utilised for the speaker connections but as the terminals seemed rather flimsy, I cut them off and soldered the output wiring directly to the speaker terminals.

Once both were done, I paired the speakers with my phone using Bluetooth and gave the neighbours a short demonstration of my favourite music.

light (or something else) in the house, the engine came to life and supplied 240VAC power. It then automatically shut down again when the last appliance was turned off.

I was informed that every electrician they could get had looked at the thing and none of them could fix it. The problem was that the engine would start OK, the voltage would start to rise and then the engine would go into its shut-down routine.

Ah-ha, I thought. No wonder the electricians couldn't fix it; what would they know about air, fuel, compression etc? This was going to be easy. And so I began my checks. The air-cleaner was OK, the fuel tank was full (and it was diesel, as it should have been) and compression could be felt when turning the engine over by hand. Of course, ignition in a diesel has to be taken on faith unless there is an obvious mechanical failure.

Serviceman's Log – *continued*

This photo shows the burnt-out windings in the toroidal transformer, caused by a hotspot created by the insulation under the thermal sensor.

There was only one thing left; the engine muffler must be blocked. My theory was that as the exhaust pressure built up, there was nowhere for the exhaust to go and the engine was choking itself.

At this stage, I needed to go back to my car to see if I had enough tools to strip down the exhaust system. As I walked back down the yard, I noticed that the junior members of the household were having great fun kicking a football over the open power lines going to the house. And then I saw it; they had managed to twist the two wires around each other.

This meant that as the voltage came up, the control circuit sensed an excess load and rather than burn out the alternator, it shut down the engine. I grabbed a long stick (quite safe with the engine not running), sorted out the twist, then went back to the engine shed and flicked the light switch. The engine sprang into life, the lights came up and the owner came tearing out of the house. "What, you've fixed it already? You're as smart as Rodney said you were!"

After that praise, it was indeed hard to tell him that it would be better if his offspring kicked the football around the other side of the house.

Digitor T-1333 sound system

Protection devices can be added to transformers and electronic circuits with the best of intentions but they themselves can also be the cause of puzzling faults. A. L. S. of Turramurra, NSW recently encountered one such puzzling situation . . .

My daughter recently complained that her Digitor T-1333 Sound System would not turn on. She used it when watching movies in her bedroom; it was small enough to fit around her dressing table and she also liked the sound.

I had previously repaired this unit about four years ago and this had involved replacing a blown toroidal power transformer. As a quick check, I removed the 1A fuse and it was completely black. This indicated a catastrophic short circuit, as per the previous fault.

So it was the same symptom but how could it be the transformer again? I told her that it may be the same problem and suggested that the repair may not be worth it. "No no!", she said, "it is just the right size for my room and the tiny speakers fit in all the right places". Then with a tilt of the head and a smile she pleaded: "Please, can you fix it for me?"

How could Dad say no?

The unit itself has a switch for "aux/5.1 surround" and a ganged volume control for five amplifiers which are basically five LM1875 power amplifier chips for front left & right, centre and rear left & right. Another LM1875 feeds a subwoofer and all of this is mounted inside the subwoofer speaker box which fits neatly into a bookshelf. There are five external speakers included with the unit, each of which is only marginally bigger than a can of baked beans and has a single 75mm driver unit (ie, no tweeter).

Power for the unit is derived via a 120VA toroidal transformer, which I had previously upgraded to a 150VA unit. This has a 12VAC secondary which is fed to rectifier diodes and two 4700µF electrolytic capacitors for the power amplifier.

At the time, I felt that the larger transformer would offer more protection. It was also labelled "heat protected" and 120VA units were no longer readily available.

Because of the new transformer's higher rating, I was very confident back then that the unit would be more reliable than before. I certainly never expected it to return with what appeared to be the same fault!

I dismantled the amplifier unit and checked out the primary resistance of the transformer. And just as I suspected, it was open circuit! I then proceeded to replace it, which was a fairly easy job as I had done it all before.

As soon as power was applied, the unit sprang to life and all the channels and the subwoofer worked perfectly! I was, however, rather worried because I had already upgraded the transformer and it should have been virtually bullet-proof. So why had two transformers now burnt out and would the latest replacement be reliable? After all, it was identical to the previous transformer and there was no room for a beefier unit, rated at say 300VA.

What's more the unit only drew a maximum of 70W, which is well within the transformer's rating.

But what if something peculiar was going on inside the unit and it got some "killer" stress from another part of the circuit – would this destroy the transformer again? My thoughts were that a thorough investigation was necessary to see if there was a hidden fault and that a long soak period would not be enough to prove it one way or the other.

After fitting the new 150VA toroidal transformer, I decided to check out the rest of the circuitry for possible problems. The first stop was to check each of the five LM1875 ICs and all the voltages were fine. There are two 3.15A fuses between the transformer secondaries and the rectifier diodes. These were OK, indicating that there was little or no stress from the amplifier chips.

LM1875s have very good protection against heat and short circuits and any faulty loudspeakers couldn't hurt the unit unduly. So, what could the underlying problem be? In the past, I have replaced many toroidal power transformers from 25VA up to 300VA and all of them had blown primary windings, probably due to the higher voltage and the small diameter wire on that side. This is nearly always due to manufacturing problems such as pinholes in the insulation, or damaged or faulty wire.

In fact, one year, I replaced over 100

power transformers in just one model of TV (all under guarantee) due to faulty manufacture! If a customer rang up and said that they had smoke and a nasty smell, I could invariably get the repair done in minutes once I had arrived at the scene!

However, in the case of this Digitor, I was not entirely convinced it was due to faulty manufacture of the transformers. After all, there were two different manufacturers involved, so surely I wasn't that unlucky?

The next step in my investigation was to check each of the six LM875s for total harmonic distortion and noise (THD+N). If there were any damaged chips, or voltage supply problems, or a lack of cooling, the distortion and noise levels would be very high. This only took a few minutes on my Audio Precision ATS-1 test set and they all came through with flying colours.

Next, I decided to have closer look at the burnt-out transformer. This had the words "130deg Thermal Cutoff" printed clearly on the side. What if it had failed simply because the thermal device had cut out and either hadn't reset or wasn't a resetting type?

There was only one way to find out: unwind the transformer and examine the thermal cut-out.

After removing all the exterior insulation and the heavy secondary windings, I began to question my own sanity for doing all this. However, I managed to justify it because the secondary wire is over 1.5mm diameter and I find it very handy to keep for those repairs which need heavy-duty wiring.

When the primary winding was exposed I could clearly see the burnt-out wires. Amazingly, they were only about 20mm away from the thermal device, an "AUPO A4-3AN3 130°C 250VAC" made by Xiamin Electronics Ltd. This device is about the size of a small transistor and it goes open circuit at about 128-132°C and stays that way until the temperature drops back to about 100°C.

As usual, the thermal cut-out had been soldered in series with the primary windings. However, the manufacturer had also sandwiched it between some rather thick cardboard to insulate it from the secondary windings but, in doing this, had inadvertently insulated it thermally as well! So what happened is that a hot spot developed under the cardboard and this had eventually caused the primary windings to short circuit and burn out!

So it would seem that the transformer manufacturer had actually created the problem. By trying to protect the transformer using a thermal cut-out device, they created a "hot spot" due to the arrangement used, which caused the windings and insulation to fail.

Now that I felt sure that I knew what the problem was, I introduced some extra ventilation around the transformer to try to keep it cool. We'll have to wait a few years to see if works though.

In the meantime, I've examined the two dozen or so toroidal transformers in my stock and I'm happy to report that none of them have "heat protected" printed on the side. SC

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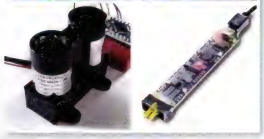

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Keysight U1282A & U1242C Cat III/IV Waterproof True RMS Digital Multimeters

The new U1282A DMM from Keysight provides a number of enhancements over its predecessors, including IP67 dust/water ingress protection, longer battery life (800 hours from four AA cells), 3-metre drop resistance and a 60,000 count display with a basic DC voltage accuracy of 0.025%. The U1242C is a lower-cost option with similar features, including IP67 protection.

Review by Nicholas Vinen

WE'VE BEEN USING the U1252B and U1253B DMMs in the SILICON CHIP office for a number of years now and we like them. The U1282A appears to supersede these, in the sense that it offers similar features and precision but has been furnished with a number of improvements. It also employs a larger, more legible LCD readout without the option of the previous OLED display and having compared them side-by-side, we think the LCD is better.

However, the most obvious improvement has to be the IP67 rating (waterproof up to 1m), which is good news for anybody who has to work outdoors or in a wet/dusty environment. The display is now a 60,000 count type (those we are currently using are 50,000 count) which means less auto-ranging and that can only be a good thing.

One feature of our existing meters we don't love is their rechargeable batteries. While this does avoid the need to open them up and buy new cells, all too often we find the battery goes flat in the middle of a session and we then have to wait for it to recharge. The meters reviewed here take a much simpler approach and use four alkaline AA cells. You do need to unscrew the rear cover to replace them but the battery life is now so long that you will rarely have to do that. Good.

The U1282A claims to last up to 800 hours while the U1242C will run for 400 hours between battery swaps. Of course, if you make extensive use of the screen back-light or the inbuilt torch (on the U1242C), use the continuity buzzer a lot, etc, you will drain the battery faster. But given that most of the time a DMM is being used it's probably just measuring voltage or current, you can expect either meter to last a long time on one set of cells.

Both new units are tested to withstand a 3-metre drop onto an unspecified surface; presumably a hard one, since you can't always arrange to have carpet or grass underfoot if you happen to drop them! This, combined with the IP67 rating, suggests that Keysight are trying to make these units attractive to electricians and technicians as well as R&D staff who would be using them in a lab environment.

The main differences between the U1282A and the less expensive U1242C are the display count (60,000 vs 10,000), basic DC accuracy (0.025% vs 0.09%), battery life (800 vs 400 hours) and some differences in features (see below). Otherwise, they are quite similar in size/appearance and have the same voltage ratings of 1000V (Cat III) and 600V (Cat IV).

Extra features

The U1282A and U1242C both have a "Vsense" feature which means they contain a non-contact voltage sensor at the top of the meter which can be activated with a button press. The U1282A also has the ability to generate square-wave and PWM signals and has

an optional low-pass filter for AC voltage measurements, to allow for accurate measurements of chopped mains voltage signals such as those used to drive induction motors from variable speed drives (VSDs).

The U1282A has an AC bandwidth of 100kHz while its cheaper sister, U1281A (without Vsense), has a 40kHz bandwidth. The U1242C has 2kHz AC bandwidth. Other features the U1282A has that the U1242C doesn't include dual display mode (eg, AC voltage + frequency) and support for probes with inbuilt pushbuttons for data hold/logging/saving. The U1282A also has up to 1µV resolution (compared to 10µV for the 1242C) and a wider capacitance measurement range of 1pF to 0.1F (rather than 100pF to 0.01F).

Interestingly, the U1242C has some features not present in the more expensive U1282A models. These include "Harmonic ratio" measurement which displays the distortion level for an AC signal and is intended for mains waveform analysis. It also has the ability to make differential temperature measurements using two thermocouples and a low-impedance voltage measurement mode to eliminate phantom readings from stray fields and capacitive coupling.

Also, as mentioned above, the U1242C has a rear-mounted white LED torch. These extra features all seem intended to be useful for electricians and field technicians, which makes sense since the U1242C should do everything they need and its lower price makes it great value for such users.

Both units have a data logging mode which allows them to store a number of readings to their internal memory, which can be later downloaded to a PC using the optional USB/optical interface (U1173, pictured). The optical interface means that not only is the PC electrically isolated from the meter (and thus it's safe to use it "live") but also it does not affect the waterproof rating.

In use

So what are they like to use? The short answer is that they work very well for day-to-day measurement tasks. As already noted. the display is easy to read, with a very quick update rate and reasonably fast auto-ranging. The LCD bargraph at the bottom of the screen is quite handy for viewing rapidly changing readings. The ambient temperature display with 0.1°C resolution in the upper-right corner of the screen is also good.

The volume of the continuity beeper is impressive and should work well in noisy environments and if you have one of the models with Vsense, a red LED at the top of the unit also lights to indicate continuity.

Speaking of Vsense, you activate it by holding down the "Null" button for 1s and the LCD bargraph then shows the detected magnetic field strength. Once you bring the top of the unit close enough to live mains wiring, the beeper sounds with a particular cadence and the red LED lights up to let you know.

The range switches have a nice chunky feel to them and all the modes are pretty easy to figure out; you would rarely have to refer to the user manual. Both units are supplied with probes with nice sharp tips and they look like they will stand up to a reasonable amount of abuse and possibly last as long as the meters themselves.

Conclusion

The U1242C offers great value as it is a quality meter with many great features and should suit casual users and electricians well. The U1282A is better suited for lab use with its higher precision and less need to switch ranges, thanks to the 60,000 count display.

If you're in the market for a quality/value or high-end portable DMM, either of these two units would be a good purchase.

To purchase either unit, or make an enquiry, contact Keysight Technologies by visiting www.keysight.com or calling 1800 629 485. A list of their Australia/New Zealand distributors can be found at www.keysight.com/main/partnerfinder.jspx?N=1+187632+187535&cc=AU&lc=eng SC

Arduino Multifunction 24-Bit Measuring Shield

Here's a low-cost PC-linked measuring system project which provides four accurate DC voltage measurement ranges together with an audio frequency level and power meter, plus an optional RF level and power meter which can operate to 500MHz.

WANT TO accurately measure voltages, decibels and power levels using an Arduino? This design combines a 4-range, 24-bit DC voltmeter with both audio frequency and RF level and power meters. The audio meter can measure up to 60V RMS (up to 900W into a 4Ω load) while the RF section will measure up to 1kW into a 50Ω load, with a frequency range extending up to around 500MHz.

Apart from the RF measurement head, everything fits into a small die-cast aluminium box (119 x 94 x 57mm) which is hooked up to a PC via USB. No separate power supply is required. The RF Head is tiny at just 51 x 51 x 32mm and connects to the main box via a standard 3.5-to-3.5mm tip/ring/sleeve (TRS) (or stereo phono jack) cable.

The unit is designed to be controlled from a PC using the Windows software we've written (for Windows 7 or later) but you could also write your own Arduino "sketch" to suit other measurement tasks.

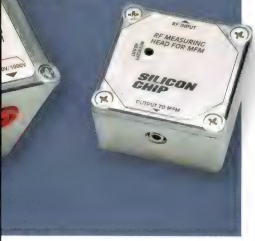
In short, this is a seriously useful and accurate test instrument that can be built at moderate cost. Refer to the specification panel for more details.

What's inside the box

Fig.1 on the facing page shows a

Pt.1: By Jim Rowe

The MFM shield PCB is housed in a metal diecast case measuring 119 x 94 x 57mm, while the optional RF Head PCB is housed in a small diecast case measuring 51 x 51 x 32mm.



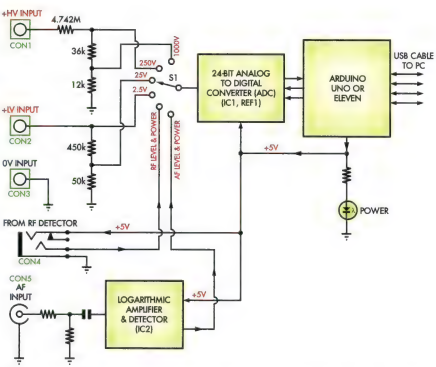
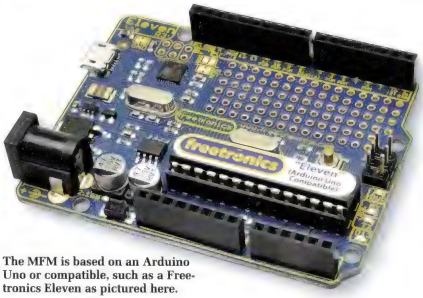


Fig.1: a simplified schematic showing the general operating principle of the Multifunction Meter. There are four inputs: low and high-voltage DC, audio level/power and RF level/power. S1 connects these inputs to a high-precision analog-to-digital converter (ADC) which is controlled by the Arduino. This in turn passes the measured values on to the PC for logging or display. IC2 provides AC-to-DC conversion for audio signals while an identical chip mounted off-board (but configured differently) feeds in RF level and power measurements via jack CON4.

simplified block diagram of the Multifunction Meter (MFM). At its heart is an Arduino Uno or compatible (eg, Freetronics Eleven or Duinotech Classic). This is shown at upper right and it controls the rest of the circuitry, including the USB link to the PC. The USB cable also provides 5V DC to power all of the meter's circuitry.

Coupled closely to the Arduino is the digital sampling "engine" shown to its left. This comprises a Linear Technology LTC2400 24-bit precision ADC (analog-to-digital converter), together with an LT1019ACS8-2.5V precision voltage reference. This combination forms a high-resolution, high accuracy digital DC voltmeter with a basic range of 0-2.5V, a resolution of 150nV (nanovolts!) and a basic accuracy of around ±0.06% (ie, ±1.5mV).

The LTC2400 is a very impressive device. It comes in an SO-8 SMD package, uses delta-sigma conversion technology and connects to the Arduino via a flexible 3-wire interface compatible with SPI and Microwire communication protocols. Other nice features include a built-in pin select-



The MFM is based on an Arduino Uno or compatible, such as a Freetronics Eleven as pictured here.

able notch filter providing better than 110dB rejection at either 50Hz or 60Hz (ie, to reject mains hum fields), very low offset and noise and a low supply current of only 200μA. It operates from a single 2.7-5.5V supply.

Range switch S1 controls the connections between the ADC and the various inputs and has six positions. Four of these are for the DC voltage ranges, while the remaining two are used for the Audio Level & Power and the RF Level & Power ranges respectively.

In the third position of S1, the +LV input connector CON2 is connected directly to the input of the ADC, giving a measurement range of 0-2.5V. In the next position, the ADC is connected

Features & Specifications

- **Description:** A PC-linked digital measurement system combining the functions of an accurate DC voltmeter, an audio level and power meter and an RF level and power meter. PC link is via USB with an adjustable sampling rate. The application software allows saving data in CSV format for later loading, plotting or analysis.
- **Power supply:** All power comes from the host PC. Draws less than 65mA from the USB port (<325mW @ 5V).

DC Voltmeter

- **Four ranges**: 0-2.5V, 0-25V, 0-250V and 0-1000V.
- **Resolution:** 24 bits (1 part in 16,777,216) corresponding to 150nV, 1.5μV, 15μV and 60μV for each range.
- **Basic accuracy:** approximately ±0.06% on 2.5V range (±1.5mV), ±0.5% on higher ranges (±125mV, ±1.25V & ±5V respectively).
- **Input resistance:** 500kΩ on the 2.5V and 25V ranges, 4.79MΩ on the 250V and 1000V ranges.

Audio Level & Power Meter

- **Input range:** 4.2mV RMS (-37.5dBV) to 60V RMS (+35.5dBV) (83dB range)
- **Frequency response:** from below 20Hz to above 200kHz.
- **Input resistance:** 60kΩ.
- **Power readout:** Watts, dBm & dBV for load impedances of 600Ω, 75Ω, 50Ω, 32Ω, 16Ω, 8Ω, 6Ω, 4Ω or 2Ω.
- **Maximum readings:**
  600Ω: 6W, +37.8dBm
  75Ω: 48W, +46.8dBm
  50Ω: 72W, +48.6dBm
  32Ω: 112.5W, +50.5dBm
  16Ω: 225W, +53.5dBm
  8Ω: 450W, +56.5dBm
  6Ω: 600W, +57.8dBm
  4Ω: 900W, +59.5dBm
  2Ω: 1800W, +62.5dBm

Front Panel Artwork

Artwork for the two labels can be downloaded from the SILICON CHIP website (www.siliconchip.com.au) as a PDF file, free to subscribers. Print these out (or photocopy Fig.6), then laminate them in clear plastic for protection and finally attach them using thin double-sided tape.

RF Level & Power Meter

- **Input range:** 15.8mV RMS (-36dBV) to 223.6V RMS (+47dBV) (83dB range)
- **Frequency response:** approximately 10kHz to 500MHz.
- **Input resistance:** 101kΩ.
- **Power readout:** Watts, dBm & dBV for load impedances of 75Ω or 50Ω (600Ω, 32Ω, 16Ω, 8Ω, 6Ω, 4Ω and 2Ω modes also available).
- **Maximum power readings:**
  75Ω: 667W, +58.2dBm
  50Ω: 1000W, +60.0dBm
- **Minimum readings:**
  75Ω: 3.33μW, -24.8dBm
  50Ω: 4.99μW, -23.0dBm

via a 10:1 voltage divider, giving a measurement range of 0-25V. In either case, the load impedance is 500kΩ.

In the fifth and sixth positions of S1, the ADC input is connected to the +HV input at CON1 via a 2-step voltage divider giving a division ratio of 100:1 for the fifth position and 400:1 for the sixth position. This gives two further DC voltage ranges of 0-250V and 0-1000V respectively.

The first position of S1 is used for the Audio Level & Power function, with the signal fed into a separate BNC input socket. Signal processing is performed by IC2, an Analog Devices AD8307ARZ logarithmic amplifier/detector device which uses a progressive compression/successive detection technique to provide a dynamic range of more than 88dB with a linearity of ±0.3dB, at all frequencies between 20Hz and 100MHz.

In effect, the AD8307 is a wideband AC-to-DC converter with a logarithmic transfer function. It converts AC signals to a DC output voltage which varies from 0.25V to 2.5V, with a nominal slope of 25mV/dB. This can be adjusted via external components, as we shall see shortly.

Finally, the second position of switch S1 connects the ADC input to the tip of CON4, which interfaces with the RF Detector Head. We haven't included this circuitry in Fig.1 but it will be covered below. It's based on another AD8307 logarithmic amplifier detector but with a different configuration, to allow it to operate at frequencies up to about 500MHz.

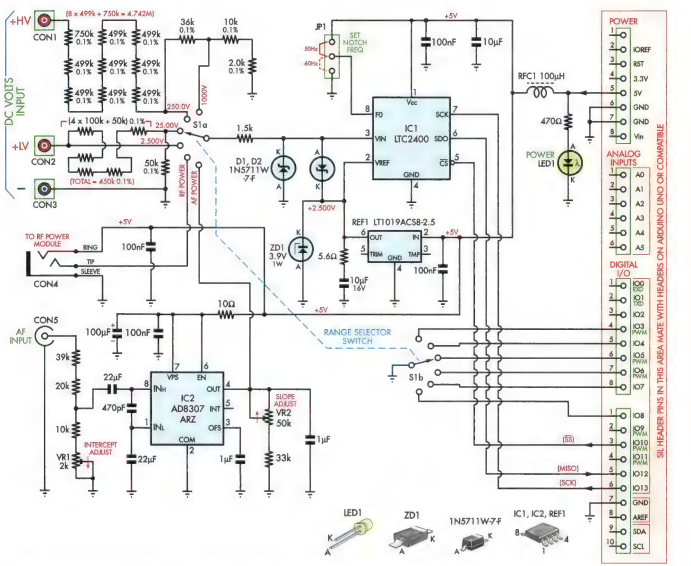
Circuit description

Fig.2 shows the full circuit diagram for the Multifunction Meter's main "shield" PCB, ie, everything apart from the Arduino itself and the RF Head. The Arduino interface is via the SIL header pins shown on the right-hand side of the circuit, while the RF level and power measurement head connects via CON4 at centre left. More on this shortly.

Fig.2 includes the LTC2400 24-bit ADC (IC1) and LT1019ACS8-2.5 2.5V reference (REF1) which were both mentioned previously. Pin 3 of IC1 is the analog input (V_{IN}), with Schottky diodes D1 & D2 providing input overvoltage protection, in conjunction with a 1.5kΩ series resistor.

The 2.5V reference from REF1 is fed to pin 2 of IC1 (V_{REF}), while ZD1 and the series RC circuit between this pin and ground both reduce any noise present in the output of REF1 and limit any voltage rise of the 2.5V reference output due to an accidental input voltage overload.

Pin 8 of IC1 is used to set its internal notch filter to either 50Hz or 60Hz, by connecting it to +5V or ground via JP1. Pins 5, 6 & 7 of IC1 form the SPI



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ARDUINO MULTIFUNCTION 24-BIT MEASURING SHIELD

Fig.2: the full circuit diagram for the MFM shield (the optional RF power head and the components on the Arduino PCB are not shown). The input switching and attenuation circuitry is shown at upper left, while the 24-bit ADC (IC1) and associated components is at upper right. The audio level and power measurement circuitry is based on IC2 at lower left, while the Arduino interface headers are on the righthand side of the circuit.

serial interface connecting it to the Arduino. Pin 5 is the "slave select" (enable) input, while pin 7 is the serial clock (SCK) input. Sample data emerges from pin 6, the serial data output (SDO), which connects to the MISO (master in/slave out) serial input of the Arduino, via digital I/O pin 5 (IO12).

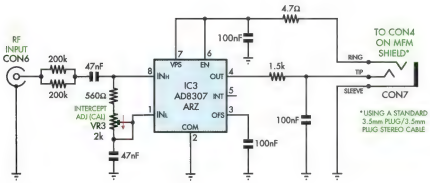
Fig.2 also shows a second pole for range switch S1 (S1b). This allows the Arduino to monitor which range the user has selected. Each position goes to a different digital input on the Arduino (pins IO3-IO8), while the rotor is grounded. These inputs have internal pull-up resistors so the firmware can tell the position of S1b (and thus S1a) by sensing which pin has been pulled to ground.

The audio level and power meter circuitry is shown at lower left in Fig.2. As noted previously, this is based around IC2, an AD8307 logarithmic amplifier/detector. Its DC output voltage at pin 4 rises by a maximum of 25mV per decibel increase in the input AC voltage, which is applied between pins 8 & 1.

The 25mV/dB slope can be easily reduced by connecting an external load resistance and this is the purpose of trimpot VR2 (50kΩ) and the 33kΩ series resistor. With VR2 adjusted to give a total of 50kΩ, IC2's output slope drops to 20mV/dB.

The audio input from CON5 is fed to pin 8 (IN_H) via a 60:1 resistive voltage divider and a 22µF capacitor, while pin 1 (IN_L) is connected to ground via another 22µF capacitor. Note that while the IN_H and IN_L pin names imply polarity, they are in fact interchangeable.

In determining the resistor values in the divider, we must consider the 1.1kΩ input resistance of the AD8307. So when trimpot VR1 in the lower leg of the nominal divider is set to 1kΩ (ie, to mid-range), the external lower leg resistance is 11kΩ, giving an effective lower leg resistance of 11kΩ // 1.1kΩ = 1.0kΩ. In conjunction with the upper leg resistance of 59kΩ, this



RF HEAD FOR ARDUINO MFM SHIELD

Fig.3: the optional RF Head circuit. Note the similarity to the audio level and power measurement circuitry in Fig.2, the main difference being that various component values and placements having been changed to expand the bandwidth out to 500MHz. 5V power comes from the main board via the ring connection of CON7, while the measurement output goes to the tip.

gives the required 60:1 ratio.

As a result, this section produces an output of 2.5V DC for an audio input of 60V RMS, falling at a rate of 20mV per dB, down to around 840mV DC with an input of 4.26mV RMS. That results in a measurement range from +35.5dBV to -47.5dBV, for signal frequencies from below 20Hz to above 200kHz.

You might wonder why VR1 is labelled "Intercept Adjust". This is because, by adjusting the input divider ratio, it controls the input level that corresponds with 0V output from IC2.

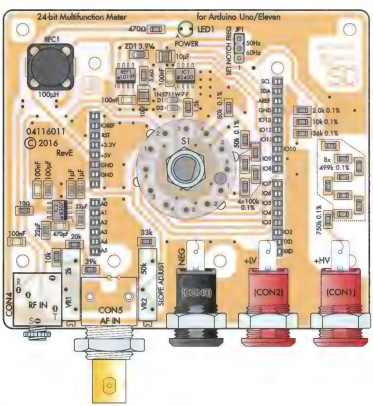
The 470pF capacitor connected between input pins 8 & 1 of IC2 is there to attenuate input frequencies above about 300kHz. This is necessary because the AD8307 can respond to frequencies up to above 500MHz, which would result in the circuit being affected by RF interference. The 1µF capacitor between IC2's output pin 4 and ground acts as a noise filter while the 1µF capacitor bypassing pin 3 (OFS) has a similar function.

The 5V DC rail which powers all these ICs comes from the PC's USB port, via the Arduino. Inductor RFC1 provides some RF filtering in case any unwanted signals have been picked up by the wiring while LED1, in conjunction with a 470Ω current limiting resistor, provides power indication.

RF input head

The RF input section is housed in a second smaller metal box and connects to CON4 on the main PCB via a 3.5mm "stereo" cable. Fig.3 shows the circuit of this section and again, it's based on an AD8307 logarithmic amplifier/detector (IC3), with a changed configuration to make it suitable for measuring RF signals up to about 500MHz. We put it in a separate metal box, to prevent any RF radiation from affecting the operation of the rest of the circuit.

In this case, the input divider values provide a nominal division ratio of 158:1, while the output from pin 4 has no external resistance to ground, giving a nominal slope of 25mV/dB. As a result, the RF head provides a 2.5V DC output for an RF input of 223V RMS, corresponding to 1000W into 50Ω or 666.6W into 75Ω. The minimum input voltage level is lower than 7.07mV



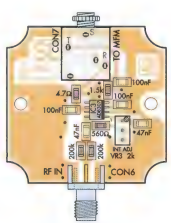


Fig.4: follow these two parts layout diagrams to build the MFM shield and RF Head PCBs. All parts are mounted on the top side of each board while CON1-CON3 are chassis-mounted and connect to the MFM shield PCB via short lengths of tinned copper wire. Be sure to fit the SMD components first before moving on to the through-hole types.

RMS, corresponding to 1μW into 50Ω or 0.66μW into 75Ω.

The RF Head receives its +5V DC power from the main MFM shield, via the same cable used to carry the output from IC3 back to CON4.

Construction

Most of the parts of the MFM are mounted on a single 96 x 83mm "shield" PCB (code 04116011) which plugs directly into the Arduino PCB via SIL pin headers. Range switch S1 is at the centre of the shield PCB, while the RF and AF input connectors are at lower left. The complete assembly fits into a large diecast box, along with three panel-mount DC input sockets (CON1-CON3) which are mounted just above the shield PCB.

All parts for the RF Head are fitted on a second PCB (code 04116012) which measures 42 x 41mm. This slips into a smaller diecast box (see photos). Use Fig.4 as a guide to assemble both boards. All components mount on the top sides of the boards.

Begin by fitting the SMD resistors, taking care not to overheat the 0.1% types. Follow with all of the SMD capacitors, which are not polarised.

Next mount the diodes (D1, D2 and ZD1) to the main PCB, then IC3 to the RF Head and IC2, REF1 and IC1 to the main PCB, preferably in that order. Finally, fit inductor RFC1. After that, only the through-hole parts are left.

Install the trimpots, taking care not to get VR1 and VR2 mixed up. BNC socket CON5 can then be fitted, followed by 3.5mm stereo socket CON4. Then fit the four SIL headers used to make the interconnections between the MFM shield and the Arduino. As you can see from the photos, these mount on the top of the MFM shield PCB, with their pins soldered to the pads underneath.

Take care to use the minimum solder necessary to make a reliable joint, as the main length of each pin needs to be free from solder, flux and dirt in order to make good contact with the matching clips in each Arduino SIL socket.

With the headers all in place, fit the 3-pin SIL header for JP1 at upper right. Then pass 20mm lengths of 0.75mm tinned copper through the three holes at lower-right on the main PCB, soldering them to the pad underneath. These will later be soldered to DC input connectors CON1-CON3. Alternatively, you can use cut-down IC socket pins as shown in the photo below but soldered connections may be more reliable.

Rotary switch S1 can now go in, after first having its spindle cut to around 17mm long (remove any swarf with a small file or hobby knife). Make sure it's orientated correctly, with the plastic post on the right side as shown in Fig.4, so the knob will go on the correct way around.

The RF Head PCB fits inside a metal diecast case measuring just 51 x 51 x 32mm. It's mounted on 12mm spacers, as shown in Fig.5.

The shield PCB can now be completed by fitting LED1. This is mounted at top/rear centre with its leads at their full length so that the underside of the LED's body is 24mm above the top of the PCB (use a cardboard spacer).

To finish the RF Head PCB, fit SMA input socket CON6 to the bottom edge of the PCB and 3.5mm socket CON7 at to the top. The SMA socket is "edge mounted", with the PCB passing through its side slots and its centre pin resting on the central rectangular pad on the top of the PCB. Solder this pin to that pad, then solder the earthy "side bars" to the matching copper pads on both the top and bottom of the PCB.

Both of your MFM boards should now be complete and ready to be mounted in the two boxes. We will describe how to do that next but **we recommend you go through the test procedure (to be described in Pt.2) first, before mounting it in the box.**

This view shows the fully-assembled PCB. We used cut-down IC socket pins to accept the tinned copper wire leads from CON1-CON3.

Preparing the boxes

The drilling and cutting details for both boxes can be downloaded from the SILICON CHIP website. There are 11 holes to drill in the main case plus one rectangular cut-out, and seven holes in the RF Head case.

Note that the rectangular cut-out is sized to suit a USB type B plug as required by the Arduino Uno or Duinotech Classic; you could get away with making a smaller cut-out for the micro-USB input on a Freetronics Eleven.

Once all the holes and cut-outs have been made, remove any burrs from the

Parts List

1 diecast aluminium box, 119 x 94 x 57mm (Jaycar HB5064 or similar)
1 lid panel label, 103 x 84.5mm
1 Arduino Uno, Freetronics Eleven or Duinotech Uno module
1 USB cable to suit Arduino module
1 double-sided PCB, 96 x 83mm, code 04116011
1 2-pole 6-position rotary switch, PCB mounting (S1)
1 instrument knob, 24mm diameter (Jaycar HK7764 or similar)
1 100µH SMD RF inductor (Jaycar LF1402 or similar)
1 3-pin SIL header with jumper shunt (JP1)
2 red panel-mount banana sockets, fully insulated (CON1-CON2)
1 black panel-mount banana socket, fully insulated (CON3)
1 3.5mm stereo switched jack socket (CON4)
1 PCB-mount BNC socket (CON5)
1 2kΩ multi-turn horizontal trimpot (VR1)
1 50kΩ multi-turn horizontal trimpot (VR2)
1 set Arduino male/female headers
4 M3 x 25mm tapped spacers
8 M3 x 6mm machine screws
4 4.5mm OD, 12mm-long untapped spacers
4 M3 x 20mm machine screws
4 M3 hex nuts
4 stick-on rubber feet
1 14-pin DIL socket (for CON1-3)

Semiconductors

1 LTC2400CS8#PBF 24-bit ADC, SOIC-8 (IC1)
1 AD8307ARZ logarithmic amplifier/detector, SOIC-8 (IC2)
1 LT1019ACS8-2.5#PBF precision 2.5V reference, SOIC-8 (REF1)
1 3.9V 1W zener diode, SC-109B (ZD1)
1 3mm green LED (LED1)
2 1N5711W-7-F Schottky diodes, SOD-123 (D1,D2)

Capacitors (all 1206 SMD)

1 100µF 6.3V X5R
2 22µF 10V X5R
2 10µF 16V X5R
2 1µF 16V X7R
4 100nF 16V X7R
1 470pF 100V C0G/NP0

Resistors (0.25W 1206 SMD)

1 750kΩ 0.1%	1 10kΩ 1%
8 499kΩ 0.1%	1 10kΩ 0.1%
4 100kΩ 0.1%	1 2.0kΩ 0.1%
2 50kΩ 0.1%	1 1.5kΩ 1%
1 39kΩ 1%	1 470Ω 1%
1 36kΩ 0.1%	1 10Ω 1%
1 33kΩ 1%	1 5.6Ω 1%
1 20kΩ 1%	

RF Head (optional)

1 AD8307ARZ logarithmic amplifier/detector, SOIC-8 package (IC3)
1 diecast aluminium box, 51 x 51 x 32mm (Jaycar HB-5060 or similar)
1 front panel label, 45.5 x 45.5mm
1 double-sided PCB, code 04116012, 42 x 41mm,
1 PCB edge-mount SMA socket (element14 2340518) (CON6)
1 3.5mm stereo switched jack socket (CON7)
1 2kΩ multi-turn vertical trimpot (VR3)
2 12mm x 4.5mm OD untapped spacers
2 M3 x 20mm machine screws
2 M3 hex nuts
1 3.5mm stereo jack to 3.5mm stereo jack cable, length to suit user requirements
4 stick-on rubber feet

Capacitors (all 1206 SMD)

3 100nF 16V X7R
2 47nF 50V X7R

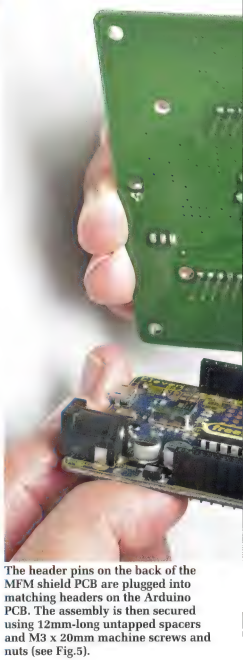
Resistors (0.25W, 1% 1206 SMD)

2 200kΩ	1 560Ω
1 1.5kΩ	1 4.7Ω

inner and outer edges with a large drill or needle file.

Box assembly

Fig.5 shows how the two PCBs are mounted. The procedure is as follows:
(1) Plug the MFM Shield PCB into the Arduino module, making sure they are properly aligned. Don't push both boards together as far as they'll go.
(2) Slip four 12mm long untapped spacers into the locations for the Arduino mounting screws between the two boards.
(3) Push M3 x 20mm machine screws up through the Arduino PCB and each spacer and fit M3 hex nuts on the top.
(4) Gradually tighten each screw and nut until the two PCBs are held together. **Note that you will need to file a small amount of metal off one "flat" of the nut used on the mounting screw that is very close to the rear end of the 10-way SIL header (the one at upper right in Fig.4) so it doesn't interfere.**
(5) Fit four M3 x 25mm tapped spacers into the bottom of the case using M3 x 6mm screws. Don't tighten these screws up fully yet.
(6) Remove the nut and lockwasher from the front of BNC socket CON5.
(7) Insert BNC socket CON5 through



The header pins on the back of the MFM shield PCB are plugged into matching headers on the Arduino PCB. The assembly is then secured using 12mm-long untapped spacers and M3 x 20mm machine screws and nuts (see Fig.5).

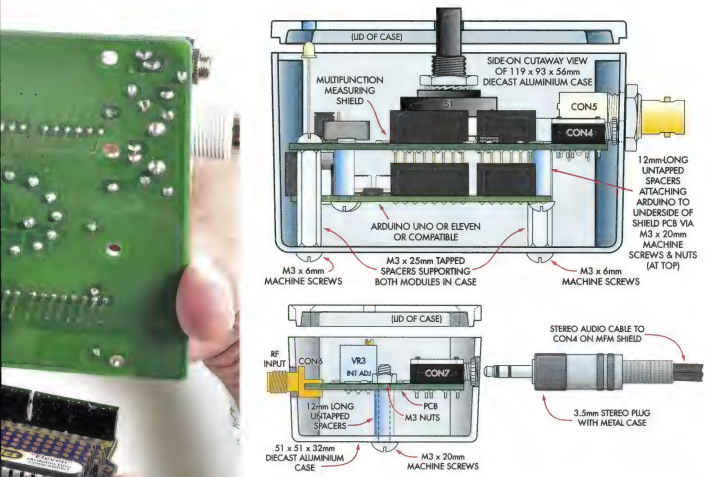
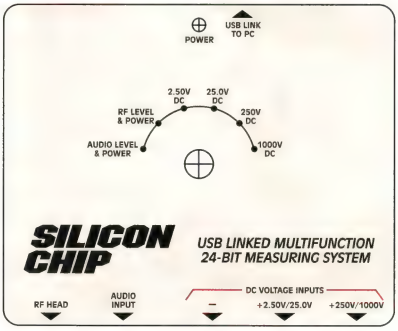


Fig.5: here's how the PCB assemblies are mounted inside the diecast cases. The Arduino board is mounted on the MFM shield PCB using four 12mm untapped spacers and secured with machine screws and nuts. The entire assembly is then mounted on the bottom of the case on M3 x 25mm tapped spacers. The RF Head PCB is secured inside its case on two 12mm-long untapped spacers.



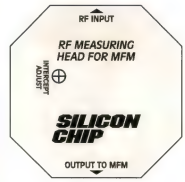
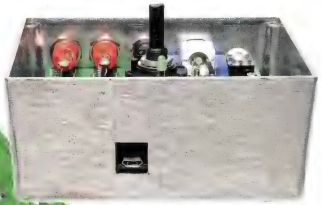


Fig.6: full-size panel artwork for the main MFM unit lid and the RF Head lid. These can also be downloaded as a PDF from the SILICON CHIP website, printed out and laminated.

Above: this view shows the Arduino PCB (in this case, a Freetronics Eleven) mounted on the rear of the MFM shield PCB.



The rear panel has a cut-out to access the USB socket on the Arduino module. Note that this cut-out can be made smaller than shown if the module is fitted with a micro-USB socket.

The PCB assembly is installed in the case by first angling the BNC socket down through its hole, then forcing the rear of the assembly down into the case. The three banana sockets are then fitted and wired to the shield PCB.

its corresponding hole in the front of the box, then force the PCB assembly down into the case until it is resting on top of the four 25mm spacers.

(8) Attach the MFM shield board to these spacers using M3 x 6mm screws, then tighten the corresponding screws in the bottom of the case.

(9) Screw the lockwasher and nut back onto the ferrule of BNC socket CON5.

(10) Remove the nuts from the three banana sockets for CON1-CON3, push them through the 12mm holes in the front of the box and slip the nuts back on. Make sure the black socket (CON3) is closest to BNC socket CON5.

(11) Rotate the banana sockets so that their tabs are horizontal and do the nuts up tight.

(12) Bend the previously soldered lengths of tinned copper wire so they pass through the corresponding banana socket holes, then solder them in place (or push tinned copper wire leads into cut-down IC sockets and then solder these to CON1-CON3).

(13) Attach the label to the lid.

(14) Drop the lid in place, ensuring that LED1 passes through its 3mm hole, then screw the lid down and attach the knob.

RF Head assembly

Use the following steps to assemble the RF Head:

(1) Push M3 x 20mm machine screws up through the two holes in the bottom of the box, then slip a 12mm long untapped spacer over each.

(2) Insert CON6 through the larger hole in the side of the box, then lower the PCB into place and slide it back so that CON7's ferrule lines up with its smaller hole opposite.

(3) Attach the board using two M3 hex nuts. Do these up nice and tight.

(4) Attach the label to the lid.

(5) Secure the lid in place, making sure that the hole to allow trimpot VR3 to be adjusted is positioned above the trimpot's screw.

Next month

Your Multifunction Meter hardware is now complete and you're ready to tackle the remaining steps such as installing the firmware and software, calibration and finally putting the instrument to use. These topics will be covered in Pt.2 next month. SC

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Automatic starter circuit for cars

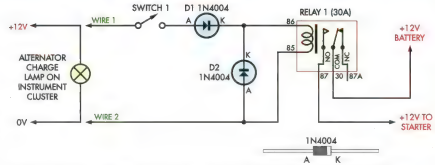
This simple circuit will operate a car's starter motor automatically when the ignition is switched on.

To start most cars today, the key is turned to the ignition position and then to the starter position until the engine has started. By contrast, this relay circuit will switch the starter motor on as soon as the ignition is turned on and will automatically switch the starter off as soon as the engine starts. There's no longer any need to turn the key to the start position.

The circuit is intended for cars with automatic transmission and it gets its power via two wire connections to the alternator charge lamp on the instrument cluster panel. Typically, the alternator charge lamp comes on when the ignition is on and will turn off once the engine has started.

As shown in circuit diagram, wire 1 is connected to the positive (+12V) lamp wire and wire 2 is connected to the negative lamp wire. These voltages can only be determined by switching the ignition on and attaching a multimeter's probes to the lamp wires.

There are two downsides to this circuit. First, it does not switch the accessories off while the starter motor is operating. This is the job of the ignition switch and car manufacturers typically switch off all accessories to reduce the load on the battery at the time of starting. Since we are not turning the key all the way to the starter position, the accessories will still be powered.



The circuit is based on a 30A relay which is wired to the alternator charge lamp. D1 provides reverse polarity protection while D2 quenches the back-EMF from the relay's coil when it switches off.

In practical terms this is not a problem and will make very little difference to the battery at the time of starting. Accessories typically include a radio, and depending on the car, will include indicators and wipers.

The second downside of the circuit is that it relies on the alternator functioning properly. If the alternator is faulty or the belt has come off, the alternator charge lamp will stay on even after the engine has started, and thus will continue to crank the starter. The addition of switch S1 enables you to switch the circuit off after the engine started, if an alternator problem is encountered.

This particular circuit is recommended for cars with automatic transmission because the starter will only operate while the car transmission is in Park or Neutral, and will not operate while the car is in Drive (due to the inhibitor switch present in such cars).

The circuit is not recommended for cars with manual transmission as the starter may cause the car to roll if it is in gear.

Both of these downsides are offset by the fact that this circuit will operate the starter motor for the shortest possible time required to start the engine and will therefore cause the least drain on the battery and wear on the starter motor.

Finally, it may be thought that this circuit could be connected to the engine check lamp instead of to the alternator charge lamp. However, this can be problematic because the engine check lamp in certain cars does not immediately switch off after the engine has started.

Alexandre Ossine,
Taylors Hill, Vic. ($60)

Mobile phone ring extender with pager

If you leave your mobile phone plugged in to charge, you may not hear it ring if you are in another room, even if your hearing is good. The Mobile Phone Loud Ringer published in the February 2013 of SILICON CHIP (see **www.siliconchip.com.au/Issue/2013/February**) is one solution to this problem but the loud piezo siren could disturb others.

This circuit solves the problem differently, by triggering a pager type unit that you carry with you. The mobile phone is placed on a base unit while charging and a piezo element in that detects vibration from the phone to trigger the remote pager.

The first circuit shown is the sensor board, with the lid of the base unit coupled to a piezo transducer, similar to the arrangement in the February 2013 project. The case lid acts as a sound board and vibration is detected with a short rod (cut from an M4 Nylon screw) between the case lid and the piezo transducer's centre hole.

Vibration gives a varying AC voltage on the terminals of PIEZO1. This is amplified by op amp IC3a which has its pin 3 input biased to half supply by a pair of 33kΩ resistors. Trimpot VR1 sets the

gain of this stage (adjusted to give best sensitivity without false triggering), while the 100nF capacitor causes it to be insensitive to signals below about 72Hz. Its output drives a charge pump-based rectifier which causes the voltage at pin 5 of IC3b to increase if vibration is detected. IC3b acts as a buffer and feeds the output to the SIG pin of CON1.

This output in turn is fed to the transmitter unit which is based on PICAXE14M2 chip IC1. IC1 monitors the analog voltage on pin 3 and also the state of pins 4-7 which are connected to jumpers that set the device's identity. When the voltage on pin 3 rises high enough (above 1.5V), IC1 transmits the pager alarm code via a 433MHz digital transmitter (Jaycar ZW3100). The data is Manchester-encoded into eight bytes and includes the ID based on the setting of LK1-LK4.

The PICAXE RFOUT command is used to encode the data. LED1 shows the status of the input signal (ie, whether pin 3 is above 1.5V), while LED2 indicates when data is being transmitted.

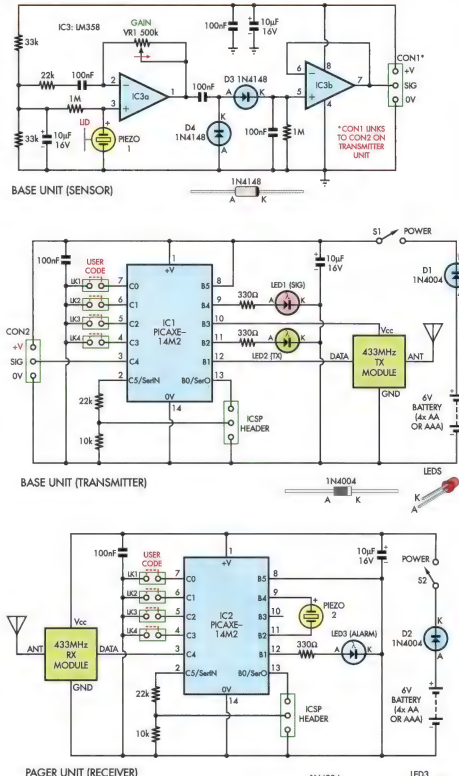
The matching receiver circuit shown also uses a PICAXE14M2 (IC2) but this time with a 433MHz receiver module (Jaycar ZW3102). It receives and decodes the message using the RFIN command. If the ID matches the setting of LK1-LK4, it sounds the alarm using a piezo transducer driven in bridge mode. This is the same type as used in the sensor module (Jaycar AB3440). When the alarm is triggered, LED3 also flashes at 1Hz.

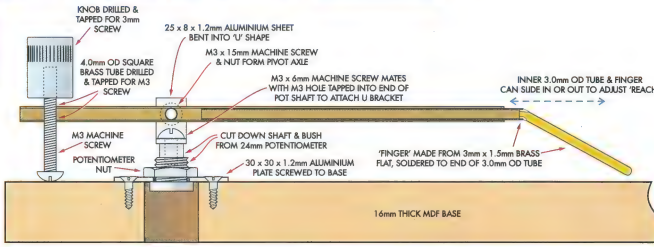
Both wireless modules require small antennas. The simplest antenna is just a 170mm length of stiff plastic or enamel coated wire, straight or coiled into a spiral. They are both powered from a 6V battery with a 1N4004 series diode to reduce the voltage to just over 5V with fresh cells while also providing reverse polarity protection. Power switches S1 and S2 are used to reduce power consumption when the devices are not being used.

Note that Altronics also have 433MHz transmitter and receiver modules which should be suitable.

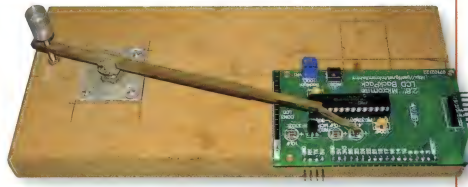
IC1 and IC2 both use the same PICAXE program. The software checks the voltage on pin 8 and runs the transmit code if high and the receive code if low. The ICSP headers allow programming with a standard PICAXE serial or USB cable. The *mobile_pager14m2.bas* program can be downloaded from www.siliconchip.com.au (free for subscribers).

Ian Robertson,
Engadine, NSW. ($85)





Third hand for soldering tiny surface mount devices



This handy soldering aid was devised to simplify the task of positioning tiny surface mount devices on a PCB prior to soldering. It is likely to be a particular boon for older readers who may be subject to the "shakes" when manipulating small parts.

The photo and the diagram tell the story. The telescopic arm is made from two sections of square brass tube which can be obtained from model railway hobby shops.

The third hand could also be used in conjunction with a USB microscope camera which would enable each SMD to be located in the exact location prior to soldering.

Ian Hawke,
Glossodia, NSW. ($80)

4-digit code lock uses Atmel micro

This circuit energises a door strike solenoid after the right code has been entered via a numeric keypad, allowing the door to be opened. In addition to the regular access code, the unit accepts a master code to allow the access code to be changed. There is a LED to acknowledge key presses and to confirm the status of the solenoid. A beeper may also be used in this position. It also has a 16x2 LCD module as a status display and it runs from a 12V DC supply.

The heart of this lock is an Atmel AVR ATtiny2313 microcontroller. Other similar Atmel micros can be used such as ATmega8 or ATmega48 with small changes to the software. The input device is a 4x3 matrix keypad, consisting of 10 digit keys (0 to 9) and two special keys (* and #).

The digit keys are used for code input. The # key is pressed after a code is entered or to enter a new code after the master code has been entered. The * key clears the entered code, allowing the user to start again.

The micro scans the keypad constantly and will unlock the door when the correct 4-digit code, or number sequence, has been entered. The expected code is stored in the micro's internal EEPROM and can be changed whenever needed.

Before turning the unit on for the first time, place a jumper on JP1. It will then display the welcome message: "Code Lock". A progress bar will appear on the left side of the second line of the display, smoothly progressing to the right in two seconds. Once the bar reaches the

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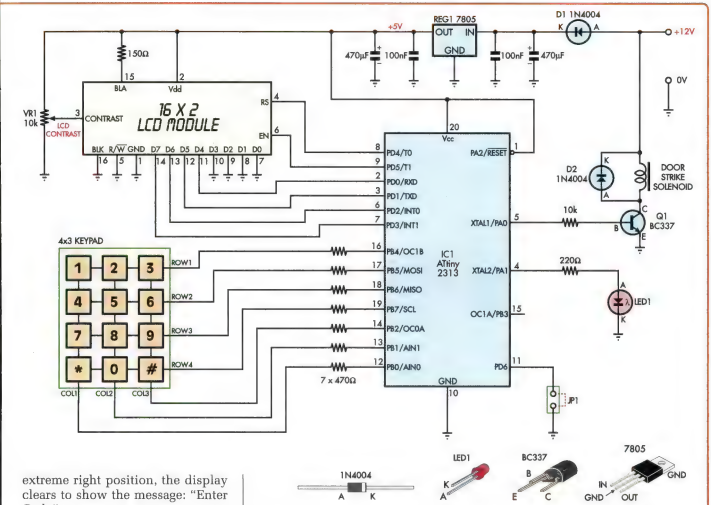

extreme right position, the display clears to show the message: "Enter Code".

The initial master code is 1234 so enter 1234#. The key strikes appear on the second line of the display as asterisks [*****]. If the code is entered in the correct sequence, it will show "Code Ok, Unlocked" and the solenoid is energised. In addition, LED1 blinks twice to confirm the unlocked status.

The procedure for changing the code is to enter the master code as explained above, then once the "Code Ok" message appears, press # and the display will show: "Enter New Code". Now input the new code and press # again. Finally, the display should show: "New Code Accepted". The new code is written to EEPROM.

Suppose the old code is 1234 and the new code is 9586. Thus the required key presses are: 1234##9586#. Now the new code is 9586# and only this code will be accepted by the micro. The master code (1234#) also serves to regain access to the code lock if the new code is forgotten or lost. This master code can only be used when JP1 is fitted, so remove this once the new code has been set.

Once the unit has been unlocked using either code, lock the door again by pressing any key except for #. The door strike will be de-energised and the display will then revert to: "Enter Code".

If an incorrect 4-digit code is entered, the display shows: "Code Invalid". A progress bar will also appear on the second line of the display for eight seconds, with LED1 blinking during this time. The display then returns to: "Enter Code". The user can try the code again to gain access.

The software, *Four-digit code lock.bas*, can be downloaded from www.siliconchip.com.au (free for subscribers).

Mahmood Alimohammadi, Tehran, Iran. ($70)

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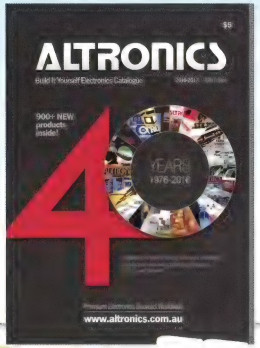

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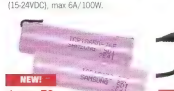

NEW!

$19.50

S 4732 With Tags
S 4736 Standard

18650 Lithium Batteries

3.7V 2600mAh. As used in many high power LED flashlights, e-cigarettes etc. Unprotected. 18.6Ø x 65mmL.

SAVE 20%

$44

M 8627A

Laptop In-Car Charger

Simply plugs into a car accessory socket & provides regulated power to a laptop. Voltages: 15, 16, 18, 19, 20, 22 and 24V DC, up to 120W. Supplied with 8 adaptors.

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D 2325

$34.95

Qi Wireless Charging Pad

A slimline 3 coil charging pad for phones equipped with Qi charging (or those fitted with a Qi case). Just put your phone on the pad and it charges instantly!

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M 8534 6/12V 4.5A 7 Stage

$225

M 8536 12V 10A 10 Stage

Multi-Stage Weatherproof Vehicle Battery Chargers

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Protected 18650 Lithium Battery

3.7V 2600mAh. Features internal short circuit protection. 18.6Ø x 65mmL.

Buy two for $15

M 8623A

SAVE 20%

$8

Handy Car USB Adaptor

Stay charged up on the road! 2A.

SAVE $19

$50

A 0276

Use at home or in the car!

Charge Up To 12 Batteries At Once

10 x AA/AAA and 2 x 9V rechargeable overnight battery charger. Keeps plenty of batteries charged for the kids toys! Includes plugpack & car socket adaptor.

S 4979 Standard
S 4980 With Tags

NEW!

$9.95

NEW!

$10.95

14500 Lithium Batteries

3.7V 800mAh. Build it into a project or convert a device to long life lithium! Unprotected. 14Ø x 50mmL.

P 7824 XT60

NEW!

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P 7825 XT90

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$8.95

XT Style DC Plugs

Male & female included. Great for battery connection.

LAST CHANCE!

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$6ea

X 2271 7W Screw
X 2281 7W Bayonet

HALF PRICE

$7ea

X 2273 10W Screw
X 2283 10W Bayonet

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Far exceeds the life of CFL bulbs. Fits standard household fittings. Warm white.

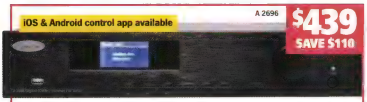
$489

SAVE $200

M 8226

Manson® Dual Tracking Power Supply

Three power supplies in one unit; two 0-30V 3A plus a 1.5-6V 5A auxiliary! Ideal for testing, repairing or R&D on equipment with split voltage rails. Built-in digital volt & current meters for precision. Independent, series, or parallel operation. • Overload & short circuit protected • Excellent regulation • 379 x 135 x 280mm



iOS & Android control app available

A 2696

$439

SAVE $110

Access over 14,000 internet radio stations from your home hi-fi!

This wireless internet radio player will compliment your existing AV system. It provides you with access to DAB+ digital radio stations, plus virtually any internet station or podcast via wireless internet (no PC required!). Plus it can stream music stored on your PC. Size: 430x90x285mm.

NEW!

A 4200

$179

2 x 50W Stereo Mini Amp

Power up speakers in your study or alfresco with this mini amp. Hooks up to A 1109 (see right) for instant Bluetooth music streaming from your phone. 3.5mm and RCA inputs. Class D design. Internal headphone amplifier.

SAVE $20

$99

S 9359

5.8GHz Wireless AV Sender

Transmit stereo audio & composite video without cables from room to room. 30m range. IR sender built in. Includes transmitter, receiver & plugpacks.

16 Channel 520MHz UHF Wireless Mic Systems

A complete wireless microphone system with your choice of handheld or beltpack mic. Offers wireless freedom when on stage. • Plugs into existing PA systems. • Crisp vocal reproduction • Ideal for clubs, restaurants, places of worship & wedding ceremonies. Up to 70m range.

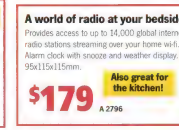
C 8867C Handheld Pack
C 8868C Beltpack Pack

New 520MHz models - work throughout Australia! Fully ACMA approved.

$339

SAVE $40

NEW



A world of radio at your bedside!

Provides access to up to 14,000 global internet radio stations streaming over your home wi-fi. Alarm clock with snooze and weather display. 95x115x115mm.

$179

A 2796

Also great for the kitchen!

SAVE $50

Pro Audio & AV Discounts

A 2544

SAVE $30

$99

Compact 2 Channel DJ Mixer

Great for beginners and mobile DJs requiring a robust lightweight mixer. Two pairs of switchable phono and line inputs, plus stereo record and amp outputs. Bass, treble and gain adjustments. Includes power supply.

SAVE 16%

A 3199A

$50

Digital Audio to Stereo RCA Converter

Great for hooking up the output of a Blu-Ray player or TV to your favourite analog stereo amplifier. Includes plugpack.

A 1115

SAVE $30

$169

Add Bluetooth® audio to your favourite speakers!

Why pay for new bluetooth speakers when you can add this 2x20W RMS module to your existing speakers? Streams music direct from your phone!

NEW!

D 2204 Windscreen

$29.95

D 2206 Headrest

Universal Tablet Holders for Vehicles.

Features secure springloaded arms for tablets up to 12.9" in size. Adjustable ball joint design. Headrest model is great for keeping kids entertained in the back seat! Windscreen mount is ideal for tablet navigation apps.

SAVE $50

D 2811

$109

Turn a dumb telly into a smart telly!

Simply plugs into a spare HDMI input and provides a tablet style interface for accessing Netflix, Stan, catch up TV apps etc! Streams 1080p HD over wireless. 1GB of RAM, 4GB internal memory & micro SD slot. Android 4.2.

NEW!

$229

A 3255

Access your USB devices up to 50m away!

Connect your home theatre to your hard drive in the study over economical Cat5 UTP cable. Only requires power at one end. No drivers required.

SAVE $100

$199

A 2554

Top Value Five Channel Audio Mixer

Compact & easy to use mixer. 5 channels accept up to 11 inputs. 3 band EQ, channel volumes, crossfader & VU meters. Great for schools and small venues.

C 0383

$35

SAVE 22%

VirtuaBly indestructible!

Drop Proof Microphone

Tough grill resists damage, even when dropped on hard floors. Ideal for clubs & schools. Includes 5m 3 pin XLR lead.

Long Distance HDMI Sender

Send 1080p from your Blu-Ray or game console up to 50m over Cat5e/6 UTP. Includes transmitter, receiver & plugpacks. W 2765 100m Cat5 UTP to suit $100.

SAVE $24

$115

A 3216A

HANDY!

NEW!

$145

A 3081C

4 Way HDMI Signal Switcher

A handy HDMI switcher for connecting up to 4 HDMI sources to a 4k/2k or HD display. Features selectable audio EDID, and audio return channel for toslink output.

NEW MODEL!

Q 1268

Long Term Temp & Humidity Logger $139

This pro-grade piece of test gear is designed for monitoring temperature and humidity levels in situ for long periods (up to 2 years battery life!). Features djustable alarms, logging periods and Windows software for viewing measurements. -40 to +70°C.

SAVE $34

X 0109

Shift dirt & grime with just water! $125

This 70W ultrasonic cleaner is ideal for delicate items such as jewellery, spectacles or car parts. Uses ultrasonic waves to clean even the tiniest of items without damage. For best results use T 3180 ultrasonic wash liquid $12.95.

Kits & Project Ideas

K 2547

NEW! $79.95

Audio Signal Injector/Tracer Kit

Ideal for fault locating in radio and audio circuits. Includes a 1kHz oscillator (injector) and in-built preamp & amp with a headphone jack (tracer).

K 4035

NEW! $149.95

Driveway Monitor Kit

Uses magnetic field detection to provide an audible and visual alert when a vehicle is detected in your driveway. Extra output can activate a mains switch for lighting etc. Ideal for gate monitoring on farms.

Test & Tools.

Measure wind speed & temperature easily.

A compact thermometer & anemometer with max speed of 108km/h. Great for ventilation monitoring, experiments etc. Includes battery. Very easy to use!

SAVE 20% $55

Q 1250

T 2555

SAVE 15% $30

Magnifier Head Goggles - Get a close up view!

Offers 1.5, 2.6 and 5.8x magnification with in-build LED lamp (requires 2 x AAA batteries).

SAVE 20% $15

T 2488

Mini Keyring Jet Blowtorch

Produces a powerful jet like flame - up to 1300°C!

- Great for hobbyists • Adjustable flame
- Refillable • One click ignition • Diecast case

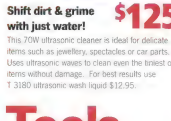
2-In-1 Multimeter & LAN Tester

Autoranging multimeter provides, current, voltage and resistance with max/data hold functions. LAN tester quickly tests lead integrity.

SAVE 22% $70

D 3020

Save space in the tool box!



Great for servicing

T 2171

SAVE 10% $35

Palm Ratchet Driver Set

A 22pc ratchet set designed for working in tight spaces. Fits in the palm of your hand, or use with the optional wrench handle. Includes driver tips and sockets.

Screwdriver Magnetizer

...and demagnetizer! An essential for the electronic toolkit.

NEW! $6.95

T 1475

Q 1281

Instant-Read IR Thermometer

Great for the kitchen or test bench! 0.1° accuracy from -50 to 260°C. Includes batteries

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T 5000

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Aluminium panels with reinforced corners & seams. Locking latches. Inner foam can be customised. 330x230x90 mm.

K 2523

NEW! $79.95

Electrocardiogram Shield for Arduino UNO

(SC Oct' 2015) Take your own electrocardiogram (ECG) and display it on a laptop. The software lets you read, display, save and print the electrical waveform generated by your heart. Requires Arduino UNO.

Datalogger Shield NEW!

SD card datalogger fitted with DS1307 real time clock for recording data to mass storage. 5V input.

Z 6380

$19.95

Z 6328

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8 Channel Relay Board

5V DC coil, popular for use with microcontroller automation projects.

Z 6339

NEW! $21.95

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Allows a 3-34V DC input to be boosted up between 4-35VDC. 2A rated.

K 4344

NEW! $41.95

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Control access by the press of a finger.

(SC Nov' 2015) The Fingerprint Access Controller stores and recognises up to 20 prints and provides quick access for authorised people. An indoor control panel allows easy setup of the system, while the fingerprint reader is mounted in the supplied wall-plate.

NEW! $129.95

K 9350

Z 6372

NEW! $29.95

Funduino Nano

Clone version of the popular Arduino Nano board. atMega328P chip.

Mini Joystick Breakout

With select button. 5V input.

NEW! $4.95

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by Alan Hughes

Digital TV and MPEG-4

The current state of play...

The recent decision by the Nine Network to simulcast in MPEG-4 has caused consternation to a large number of TV viewers. This chaos is largely because TV sets were not required to be MPEG-4 compatible. So what is next?

At the start of last year, some 90% of TVs in use were capable of displaying the sharp images produced by full-HD broadcasts and Blu-ray discs.

But virtually all TV broadcasts were in the much lower quality standard definition (SD), with the exception of some from One, SBSHD, 7Mate and GEM.

Those exceptions are being broadcast with a degraded HD signal where the image is cut up into 1440 columns instead of 1920 columns, causing jagged edges in the image.

The TV networks did this to increase the number of programs which can be broadcast from a single transmitter.

Then, on 5th November 2015, the Nine Network, covering 60% of the Australian audience, started higher definition MPEG-4 broadcasting on channel 90, using 1920 columns, to provide much sharper pictures on their most popular programs.

At the same time, Channel 9 continues to simulcast the same program in standard definition (SD). This means no viewer goes without Channel 9 programs, even if they cannot receive channel 90.

Fitting a new high definition signal into existing transmissions did present a major problem for the Nine Network. The easiest change would have been to replace 9GEM with 9HD programs but an additional 33% data capacity would have been required and this would not fit into their existing transmission channel.

This is where MPEG-4 Advanced Video Coding, otherwise known H.264, came to the rescue. It requires 50% less bandwidth than MPEG-2 for equivalent video quality. Nine decided to use MPEG-4 to reduce the 9HD data rate to accommodate the 33% increase and it still leaves enough capacity to transmit 9GEM in standard definition.

MPEG-4 AVC was already being used when Nine started 9HD. Racing.com started using H.264 on the Seven Net-

work's channel 78 and the Prime7/GWN7 networks started on 29th August 2015. 4Me (channel 74/64) is now broadcasting with MPEG-4 while NBN, WINHD and the Ten Network started in March this year.

Note that all existing HD channels still use AC3 audio encoding, at about 480kbit/s, which occupies a fairly significant proportion of the bandwidth.

Sound is much more efficiently compressed by Advanced Audio Coding (AAC) which is being used for Racing.com, 4ME and 7Flix at around 70kbit/s.

Many sets will not decode MPEG-4 signals and so will produce a blank (usually blue) screen and perhaps a message. No one actually knows what proportion of TVs will receive MPEG-4 signals. The Australian Communications and Media Authority has been advised that 80% of receivers are MPEG-4 capable but they provided no reference for this statistic.

All of the set-top boxes provided free to pensioners are MPEG-4 capable. Sony has publicly stated that all their TVs sold from 2009 are MPEG-4 capable. Typically, TV manufacturers' specification tables do not mention what compression methods they will accept.

All Freeview products released since 2009 are MPEG-4 capable. In the meantime, if you have set which is not MPEG-4 compatible, you will need a set-top box which can do the job. Make sure of that aspect before you buy.

When a sufficient proportion of receivers are MPEG-4 capable, Channels 2, 3, 5, 6, 7, 8, 9, 10 should become FHD and 30, 80, 90, 13 and other yet to be specified change to SD at a low data rate like that used by 4ME.

Along with this change, all secondary programs should be MPEG-4 compressed enabling allowing One, 7Mate, 9GEM to return to FHD alongside the primary program. This will maximise the viewing of the sharper pictures.

Why was this chaos allowed to happen?

MPEG-4 is not new; far from it. The MPEG-4 version 10 compression standard was approved for worldwide use in 2005 and New Zealand has used MPEG-4 for all of their TV broadcasts. In Australia, we have had digital TV since 2001 but using the less efficient MPEG-2 compression.

The root of the chaos lies in Australian Standard AS 4933.1-2010 *Digital television - Requirements for receivers – VHF/UHF DVB-T television broadcasts*. This standard made MPEG-4 reception optional, saying that broadcasters may use it and so importers and retailers do not have to comply. If the standard had made MPEG-4 compulsory back in 2010, nearly all TVs, personal video recorders and set top boxes would now be able to receive MPEG-4 signals.

As recently as January 2015, the Department of Communications asked for submissions to a "Digital TV Regulation" enquiry.

Every broadcaster rejected MPEG-4, preferring to wait for Ultra High Definition, but none of them suggested any concrete plans on how to achieve it.

Right now, every broadcaster *could* transmit two or three of their programs in full high definition using MPEG-4 video with progressive scan, accompanied by HE AAC V2 sound.

Progressive scan

All of the AS4933 versions of the standard specify that all HD TVs must be able to display film mode, now called "full high definition" by TV manufacturers and retailers.

All commercially produced Blu-ray discs use full high definition which includes progressive scan to minimise jagged edges, particularly on curves and diagonal detail in the pictures. Look at the lines on a tennis court during tennis telecasts. Progressive scanning also causes a reduction of the data rate in complex moving pictures.

TV technology has changed since the picture tube TV was retired. Typical flat screen TVs show each frame up to eight times (at 200Hz), modifying each repeated frame to provide smooth motion display.

Modern TV & video cameras are all digital now and so are natively progressive scan. There is no longer any reason to broadcast interlaced content. Older shows recorded on video tape, can be converted to progressive scan. It is up to the broadcasters to utilise progressive scanning in all equipment including compressors, so as to match the quality of Blu-ray discs.

Ultra-high definition 4K TV signals (as used in cinemas) and computer screens are all progressively scanned.

Pixellation problems

HD/SD simulcast can cause pixellation and other artefacts, particularly during sporting broadcasts. This is because they use statistical multiplexing to maximise the number of program channels they can transmit.

A TV channel can carry 23Mbit/s, of which a statistical multiplexer allocates a portion to each program stream. More of the data is allocated to images containing more detail and motion than static images of little detail.

But unfortunately, an HD/SD simulcast has a pair of channels where the greatest demand occurs at the same time, because the images are similar and therefore the bandwidth available to each channel is insufficient to provide the required image detail. As a result, simulcasting should be terminated as soon as possible.

The chaos will continue

Since MPEG-4 was standardised, television technology has improved its efficiency through the standardisation of DVB-T2 and HEVC (H.265).

DVB-T2 increases the data capacity of an "over the air" TV transmission channel by 44% compared to H.264. It is now in use in 37 countries, including the UK and all of Russia.

High Efficiency Video Coding (HEVC) halves the data rate for MPEG-4 and is currently required for watching Netflix in UHD. Germany has been broadcasting UHD test signals in Berlin for a year at medium power.

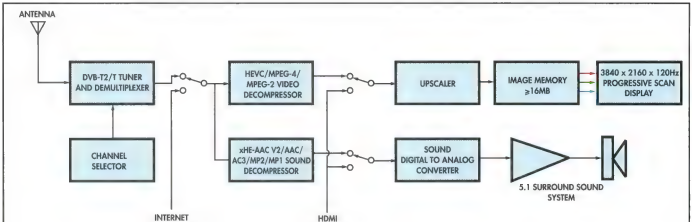
The USA broadcasters are now pushing for ATSC 3.0 using a version of DVB-T2 and HEVC to be rolled out as part of their digital repack. We did a similar restack, which was completed in 2014.

AS4933.1-2015 *Digital television - Requirements for receivers - VHF/UHF DVB-T television broadcasts* make no mention of the Australian use of DVB-T2 or HEVC and was published six months after the DTV regulation inquiry.

Hence consumers are not being informed how to "future-proof" their TV purchases, particularly when so few TVs currently available are future-proofed.

Preventing the recurrence of chaos

All TV receivers which are not compliant with the current version of AS4933.1 should immediately be banned from importation and sale, to protect the public.



A functional block diagram of a "Futureproofed TV" containing over-the-air reception, hybrid broadcast broadband for catch-up TV and the use of external devices.

AS 4933.1-20## *Digital television - Requirements for receivers - VHF/UHF Terrestrial television broadcasts* needs to have the compulsory requirement for DVB-T2 and H.265 support added. ACMA, through the Customs Act, has the power to make it compulsory and should do so.

Currently all Sony, some Panasonic and some Samsung TVs are DVB-T2 capable. Hisense is the only manufacturer to state in their specification that their UHD TVs are H.265 or HEVC capable; unfortunately, they are not able to receive and decode DVB-T2.

Many manufacturers do not quote the type of compression and modulation they will receive in their specifications. MPEG-4, HE AAC V2 sound, HEVC and DVB-T2 technologies are not backwards-compatible.

The inclusion of the newer technologies makes little difference to the price of new receivers, when employed in very large numbers. However manufacturers must specify which types of signal they can receive.

Future options

If all broadcasters convert to DVB-T2 modulation and HEVC compression on each program regardless of the definition, then each broadcaster will be able to transmit a main program in ultra-high definition and still transmit their existing secondary channels.

If this occurs within seven years' time it will give viewers time to replace their TV sets and also for broadcasters to upgrade the modulator in every transmitter in Australia.

Netflix requires a stable download speed of 25Mbit/s for UHD programs and many people who are yet to get the NBN will never be able to achieve this speed.

To get the signal to the viewer, the price is fixed using broadcasting, whereas when broadband is used the price rises as the number of simultaneous viewers increase.

It would appear that all other broadcasters will expand their use of MPEG-4 compression this year. A major chain store is still selling MPEG-4 capable HD set top boxes for under $30. Connect it to a digital TV using an HDMI cable to be able to see available programs with the sharpest images possible.

Free TV Australia, ABC, SBS, the Department of Communications, ACMA, importers and Choice should include DVB-T2, HEVC and HE AAC V2 sound in an updated AS4933 to speed the introduction of ultra-high definition TV from all broadcasters and to protect the investment by viewers.

Future-proofing TVs

A DVB-T2 tuner is capable of receiving signals containing 40% more data for the same bandwidth as MPEG-4 AVC. The channel selector which is controlled by the remote control, selects the transmission channel and the selected program within that channel.

The decompressors are fed with either the off-air or catch-up/streamed programs, which both need their pictures and sound decompressed. The HDMI input is used for Blu-ray players etc, which supply uncompressed digital signals.

The video is then up-scaled unless it is ultra-high definition already. Then the image is stored, decoded into red, green and blue signals for display. The image memory is read in sequential order and fed to each pixel in the display in turn.

Off-air and internet sound has to be decompressed and then converted to analog for amplification and feeding to speakers.

Up-scaling is magnification

Ultra-High Definition images have the highest number of picture elements; lower definition images contain fewer pixels. The diagram overleaf shows the image sizes for all types of signals from commercial cinema at 4096 x 2160 (ie, 4K) down to American SD TV at 720 x 480 pixels.

The thick line shows the edge of the screen. A true UHD signal will fill the screen. Since 4K movies have slightly more columns than UHD TV (4096 vs 3840), this results in 3.5% cropping on the left of the screen and another 3.5% on the right. Poorer resolution images contain fewer pixels and hence would only cover part of the screen if shown pixel for pixel.

Viewers tend to like images which fit the full screen. To achieve this, the manufacturers have to magnify the lower resolution images. Magnification or up-scaling is achieved by interpolating adjacent picture elements.

Picture elements or Pixels

A pixel is the smallest area in an image which can change colour. If you graph the output of a camera which is panned across a star, you will get the voltage output shown below,

Horizontal Resolution	# Incoming pixels/line	# incoming sample	# outgoing sample to display	Magnification by area
Ultra-high definition	3840	1	1	1
Full high definition	1920	1	2	4
Aust HD	1440	3	8	5
ABC24 (720p)	1280	1	3	9
SD World	720	3	16	20
SD America	720	3	16	24
Racing.com	640	1	6	23
4ME	528	11	80	27
Vertical Resolution	**# Incoming Lines/frame**	**# Incoming sample**	**# outgoing sample to display**	
UHD	2160	1	1	
FHD	1080	1	2	
Aust HD	1080	1	2	
ABC24	720	1	3	
SD World	576	4	15	
SD America	480	2	9	
Racing.com	576	4	15	
4ME	576	4	15	

The number of pixels per line and lines per image for common TV broadcast resolutions.

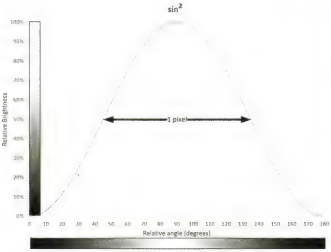
as the lens will make the star appear circular; the higher the definition, the smaller pixel diameter.

The objective is to recreate the pixel size on the UHD screen which matches that of the lower resolution image original.

UHD cameras provide the sharpest images for UHD displays. Up-scaling does not usually increase the sharpness of lower resolution images; this would require a sophisticated algorithm which would generate detail which was not recorded in the original video. Such algorithms do exist (see http://www.cs.huji.ac.il/~raananf/projects/lss_upscale/sup_images/) but this requires significant processing power and most TVs do not have this capability yet.

High Frame Rate TV (HFR)

Commercial Blu-ray discs are recorded at 24 frames per second which is the standard moving picture film speed. With the exception of the Americas and parts of Asia, progressive scan TV has a frame rate of 25 frames per second. New UHD/4K programs can have a frame rate from 24-120fps, however broadcast TV and Internet streaming video will probably be limited to 60fps.



The brightness level output of a single-pixel image sensor as it passes over a pixel-sized bright object such as a star.

At the moment, there are no broadcasts at these frame rates. Higher frame rates create very smooth movement in the image.

As noted above, current 200Hz TVs show each frame eight times. The better TVs calculate the vectors of movement and modify the repeated frames to smooth the illusion of motion which removes jerky movement. But high frame rate signals give more natural results.

High Dynamic Range TV (HDR)

Current displays are capable of much better contrast ratios than the old fashioned cathode ray picture tubes (CRTs). Currently, most displays have a pixel colour depth of 8 bits each for red, green and blue, giving 256 brightness levels (2^8) . To take full advantage of the high contrast ratio of newer displays, HDR programs will use 10 bits per luminance sample, giving 1024 brightness levels (2^{10}). This increases the maximum possible contrast ratio by four times, to over 1000:1.

Wider range of colours

It's also possible for modern displays to have an extended colour gamut. Greens and reds can be much more saturated, along with the ability to prouce longer red photon wavelengths. UHD/4K cameras are designed to be able to

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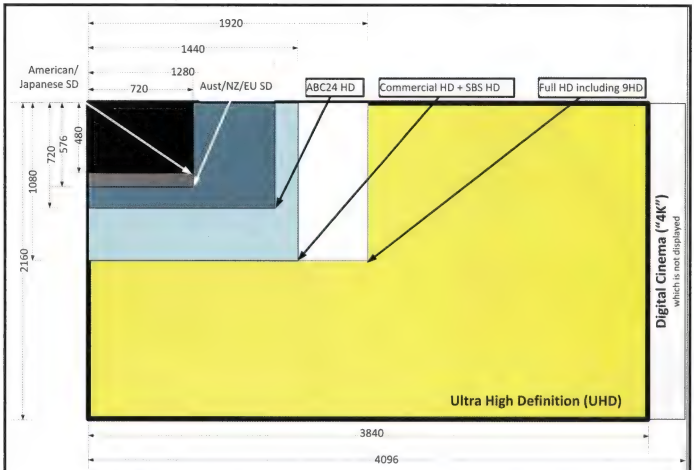

Graphical representation of the various definition standards currently in use. Australia and New Zealand SD is the grey area, top left of diagram. Compare this to Ultra High Definition (yellow) – in fact, there is no comparison!

capture a wider range of colours and laser/OLED displays can display them.

Hybrid Broadcast Broadband TV

This system is being used by broadcasters for catch-up TV, as shown in the Freeview advertisements. HbbTV 2.0 is the next upgrade from FreeviewPlus.

It will require HEVC/HE AAC v2 (with 5.1 surround sound) compression to minimise data rates for everything from phones to UHD TV.

Receivers will be able to store programs for Video On Demand.

Worldwide digital TV standards

North America and South Korea transmit ATSC which uses MPEG-2 compression and a poorly performing, essentially serial data transmission system. They have developed ATSC 3.0 which is similar to DVB-T2 and will use HEVC compression and they are pushing for its adoption.

Japan, parts of South America, Philippines, Sri Lanka and Botswana use ISDB-T which is similar to DVB-T2, including MPEG-4 or MPEG-2 compression.

DVB-T2/MPEG-4 is already in use in 37 countries including the UK's HD programming, and Igloo pay TV in NZ. It has been adopted by 73 countries. The balance of the world is using DVB-T.

For those with poor hearing and eyesight

All digital TVs are capable of displaying sub-titles for those with difficulty hearing. The Closed Captions are coloured according to who is speaking and also describe off-screen sounds.

Until the end of June this year there is a trial of Audio Description on ABC iview for those with poor eyesight. The scene is described during gaps in the dialog. http://iview.abc.net.au/programs/audio-description-a-new-feature-on-iview/IV1462H001S00

The series of Advanced Audio Compression standards specifies that an Audio Description channel is available and the sound is mixed with the main sound in the receiver, when selected by a button on the remote control.

In the UK 10% of all programs are broadcast with Audio Description.

For the future

From now on all TVs need to support DVB-T2/T, HEVC/MPEG-4/MPEG-2 video and MPEG-1/AC3/HE-AAC sound. Upscaling support will be required for lower resolution content.

Once the integrated circuits for the above functions are designed and manufactured for a worldwide market, the increase in TV cost should be very small.

Note: as this article was going to press, TEN, NBN and WIN began Full HD broadcasting with MPEG-4 AVC. SC

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Vintage Radio

By Ian Batty

The Westinghouse H-618 6-transistor radio

Released in 1957, Westinghouse's H-618 transistor radio employs a fairly standard circuit design but has its own contemporary styling. Unlike many sets of the era, it uses a transistor as a Class-B demodulator, rather than a conventional diode detector.

It's America in the 1860s. Railways are crossing the country, opening up the vast continent. The West is reached by travelling over the lofty Rocky Mountains. Going up is manageable if slow but coming down the inclines is a different matter, with perhaps hundreds of tons pushing a train forward with ever-increasing speed.

Engineers solve the problem by adding brake vans – rolling stock fitted out with manually-operated brake shoes bearing on the wheels. Brakemen are forced to run across the roofs from one van to another, applying or reducing the brakes as needed.

Engineer George Westinghouse gets his first big break in 1868 when he invents and patents a braking mechanism using compressed air. This allows individual brake mechanisms to couple into a master system.

Thomas Edison, having invented and marketed the light bulb, set up his direct-current electrical distribution system in 1882. However, DC's drawbacks prompted Westinghouse to explore alternating current (AC). The "War of The Currents" took off, with AC eventually gaining the upper hand following Nikola Tesla's invention of the polyphase induction motor in 1883 and the production of a full working model by 1888. It's still the preferred design for electric motors rated in the kilowatts to megawatts range.

From those early years, Westinghouse Corporation expanded rapidly into the giant that it is today. It's now involved in everything from kitchen appliances to nuclear power systems and jet engines.

The Westinghouse H-618

Westinghouse's involvement in semiconductors, like that of Western Electric and General Electric, took off during the 1940s. During that time, the company was involved in researching and supplying diode mixers for wartime radar equipment. When Bell Labs subsequently invented the transistor in 1947, Westinghouse joined other manufacturers in the race to produce working, marketable devices.

One of Westinghouse's early transistor radios was the H-618 which was released in 1957. In contrast to contemporary GE designs, Westinghouse opted for the "standard six" configuration but added a Class-B demodulator instead of using a conventional diode. As a result, the H-618 is really a 7-transistor radio.

While diode demodulators work just fine, they create as much as 20dB signal loss. Considering the moderate added cost of one transistor, Westinghouse's design makes good sense given the improvement in performance. It also meant that the set could be marketed as having seven transistors rather than "only six".

Another advantage of the H-618 is that it's a 9V set and runs from a single battery. It sets aside the oddball voltages and tappings used in other, early transistor sets.

Given its size, it's obviously not a "shirtpocket" set, especially as it also needs to be operated "right-way-up" rather than vertically because of its horizontal ferrite rod antenna. Visually, it's very much a 1950s/60s design. The font used for the tuning dial, its arched top, lightly "keystoned" sides and arrow-head speaker grille all give it the stamp of "modernity" that characterised this era.

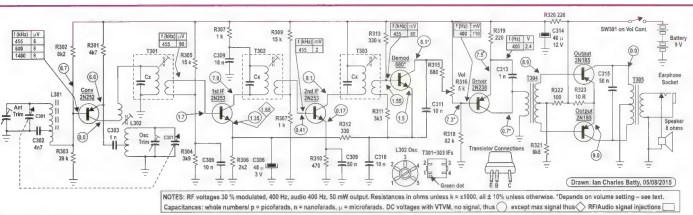


Fig.1: the Westinghouse H-618 is a 7-transistor superhet design, with a self-oscillating converter and two IF amplifier stages. A type 880 transistor is used as a Class-B demodulator (detector). This feeds a 2N238 audio driver and this stage in turn drives a push-push output stage (2 x 2N185) via phase-splitter transformer T304.

It makes a fine contrast to the stark, minimalist styling of the Regency TR-1. It even has an attractive light mother-of-pearl effect on the white tuning dial background.

TI transistors

One interesting design aspect of the H-618 is that the transistors were all made by Texas Instruments (or, at least, they were in the set pictured here). In fact, beginning with the first transistor portable (Regency's TR-1), TI transistors dominated early designs.

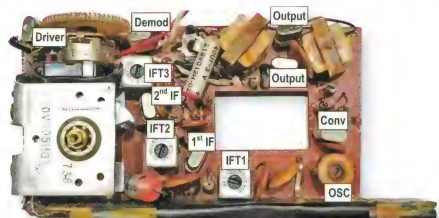
The tuning gang used in the set pictured here carries a "738" stamping and this places the set's production in the latter part of 1957. This is further confirmed by a "57" serial number on the loudspeaker.

Being an American set of the 1950s, it also carries the CONELRAD station markings. These markings consist of two small red arrowheads on the lower dial section, plus an arrowhead in red circle on the dial knob. During an emergency, tuning the red circle to one of the arrows would bring in a CONELRAD station.

So what was CONELRAD? Basically, it stood for CONtrol of ELectronic RADiation and was a system that, in the event of a nuclear attack on the US, would close down all television and FM radio stations. Some remaining AM stations would then broadcast information on 640kHz or 1240kHz in a "round robin" roster to frustrate any enemy attempts to use radio direction finding. CONELRAD was decommissioned in 1963.

Circuit description

This set uses a mix of NPN and PNP transistors (all from Texas Instruments) in the classic TO-22 can. It's common to see NPN transistors in the RF/IF section, due to their superior RF performance, and lower-cost PNPs in the audio stages where their poor high-frequency response isn't a drawback.



This view shows the parts on the top of the PCB, with the metal shield and the loudspeaker removed. The shield obscures the tuning slugs in the oscillator coil and the first and second IF coils when it is in place.

Unusually though, the H-618 uses the PNP 2N252 as a converter.

Fig.1 shows the circuit details. The incoming RF signal is picked up by a ferrite-rod antenna and fed to a self-oscillating converter stage which uses emitter injection. The only unusual point is that the antenna coil is connected directly to the transistor's base, with the blocking capacitor (C302) between the rod's ground tapping and circuit ground.

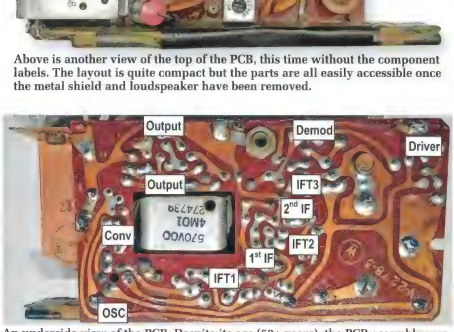
This stage, like almost all self-oscillating converters, uses fixed bias. Its collector output feeds the untapped, tuned primary of T301, the first IF transformer.

T301's untapped, untuned secondary feeds the base of the first IF amplifier transistor, a 2N253. This stage is not neutralised and feeds the untapped, tuned primary of T302, the second IF transformer. The stage is also subject to AGC (automatic gain control), as fed back from the demodulator. Its emitter is bypassed using electrolytic capacitor C306 but electrolytics really are a "no-no" at radio frequencies (RF). Indeed, this set wasn't working properly because C306 had deteriorated, as detailed later.

As shown on Fig.1, the AGC voltage is applied to the first IF amplifier's emitter, with its base voltage fixed by resistive divider R305 & R304. This is a somewhat unusual arrangement.

The second IF amplifier (another 2N253) is fed from the untapped, untuned secondary of T302. This stage works with fixed combination bias and like the first stage, is not neutralised. Its collector feeds the tuned, untapped primary of T303,

Above is another view of the top of the PCB, this time without the component labels. The layout is quite compact but the parts are all easily accessible once the metal shield and loudspeaker have been removed.



An underside view of the PCB. Despite its age (58+ years), the PCB assembly was in good condition and replacing just two electrolytic capacitors was all it took to restore the set to full working order.

the third IF transformer, and T303's secondary in turn feeds the demodulator.

Demodulator

The demodulator also uses an NPN transistor, either a type 880 or a 2N94 (as in the set featured here). This stage has minimal forward bias applied; just 50mV, in fact. This weak forward bias allows the transistor to respond to the incoming IF signal from T303's untuned secondary, so that it acts as a rectifier.

The demodulator fills two roles. First, it rectifies the incoming IF signal which is then filtered by 10nF capacitor C311 to recover the audio component. This audio signal is then fed to volume control R316 via resistor R315.

The inclusion of R315 may seem odd at first glance, since it reduces the audio signal level to some extent. However, it's necessary to provide a minimum load for the demodulator when the volume is turned all the way down (ie, when the wiper goes to the positive supply rail). Conversely, as the volume is turned up, the first audio stage (a 2N238) loads the demodulator more and more.

Without resistor R315, audio distortion would become noticeable as the volume was wound down and the load dropped below a certain value. R315 prevents this and because the demodulator also gives useful audio gain, the loss across R315 is tolerable.

Depending on its setting, the volume control also provides load resistance for the demodulator and acts as an attenuator for the signal going to the audio driver stage. The net effect at low volume settings is low gain (due to a low load impedance) coupled with high attenuation. As the volume control is advanced, the demodulator's load resistance increases and the attenuation is reduced, so the overall gain increases.

The demodulator also responds to increasing IF signals by increasing its collector current. It shares an emitter resistor (R306) with the first IF amplifier and that stage has a very tightly-controlled base voltage which provides the usual forward bias of around 200mV under no signal conditions.

In operation, it doesn't take too much demodulator current to increase the voltage across R306 and slash the first IF amplifier's forward bias. Even 50μA of extra demodulator current will increase R306's voltage drop (and thus reduce bias) by some 100mV; enough to drive the first IF stage towards cut-off.

Changes in the demodulator's collector current (due to signal strength) and the setting of the volume control both influence the audio driver's bias to some extent. The most significant change is the driver's collector voltage, dropping from 0.7V at full volume to 0.26V at minimum volume.

The audio driver stage (2N238) operates with combination bias (volume control R316) and unbypassed emitter resistor R319. This part of the circuit looks to be "upside down" but that's simply because the 2N238 is a PNP device.

Typically, the output from the demodulator will be around 110mV, so there is significant audio gain in the Class-B demodulator. Because of this, the audio driver's emitter resistor is unbypassed, thereby significantly reducing the gain of this stage to prevent overload. By comparison, a diode demodulator would deliver no more than about 10mV of audio.

The audio driver feeds a conventional Class-B push-pull output stage via phase-splitting transformer T304. The output stage uses the popular 2N185 transistors, with fixed bias provided via divider resistors R321 & R322. The service notes stipulate that these transistors must be a matched pair.

The collectors of these transistors then drive the loudspeaker via centre-tapped output transformer T305. Note that the emitters of the 2N185 transistors connect to the positive supply rail via shared emitter resistor R323, while output transformer T305's centre tap goes to ground.

Cleaning it up

As it came to me, the set was in good cosmetic condition and just needed a clean and polish to bring it up nicely.

The set was available in grey, black and red, each with a different model number: 617 (grey), 618 (black) and 619 (red). All three versions use the same circuit.

However, applying power resulted only in loud, uncontrollable squealing. At least the audio stages were working but where was this crazy feedback (oscillation) coming from?

At that stage, I recalled my experience with the Regency TR-1. It had been pretty well dead when I got it and I'd suspected faulty coupling and bypass capacitors in the audio section. Replacing dried-out electrolytics in the audio section had subsequently created a very similar oscillation noise to what I was now hearing.

The Westinghouse H-618 is unusual in that it employs only two electrolytic capacitors: (1) power supply decoupling capacitor C314; and (2) first IF stage emitter bypass capacitor C306 (just like the TR-1). Replacing both electrolytics returned the set to normal operation and I now had a well-performing radio.

As in the GE 675 (Silicon Chip, September 2015), this set uses a metal plate to cover most of the component side. This plate is secured by twisted lugs and one soldered connection to the PCB. It supports the loudspeaker and also provides a degree of shielding to ensure stability in a set that isn't neutralised.

Unfortunately, it also obscures the adjustment slugs for the local oscillator coil and the first and second IF transformers. While it's possible to remove the cover (as I did for this article), it would be preferable to leave it undisturbed in a set that's working correctly.

The ferrite rod antenna is connected to the PCB via metal straps rather than via thin wires (as in other sets). These straps not only make the connections more reliable but also support the ferrite rod on the PCB.

How good is it?

The H-618 is a mature "standard six" design, so it should be a good performer. Its sensitivity is specified as 200µV/m or better, while the audio output is listed as 100mW or more.

So how does it stack up in practice? The measured RF sensitivity is 150µV/m at 600kHz and 1400kHz for 50mW output, with signal-to-noise (S/N) ratios of 12dB and 10dB respectively. For the usual 20dB S/N ratio, the RF sensitivity is 250µV/m at 600kHz and 300µV/m at 1400kHz.

The IF selectivity is ±4.5kHz at -3dB and ±52kHz at -60dB which is quite respectable. The AGC response is also

MISS THIS ONE?

CLASSIC

Published in Feb 2013

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THD is almost unmeasurable at 0.001% @ 1kHz and S/N ratio is outstanding at 110dB.

Most parts mount on a single PCB and the hard-to-get parts (PCB, front and rear panels, programmed micro, SMD parts and coloured RCA sockets) are available from the Silicon Chip On-Line Shop.

You'll find the construction details at siliconchip.com.au/project/classic+dac

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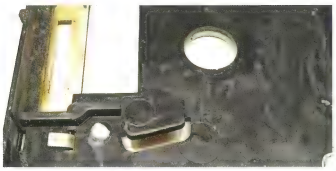

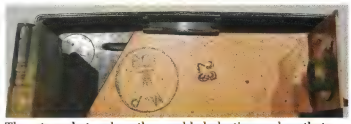

These two photos show the moulded plastic case lugs that are used to help secure the loudspeaker (left) and the chassis (above) – see panel.

Special Precautions

The Beitman service sheets recommend monitoring the current drain under test, probably due to concerns about self-heating in the output transistors. In my case, testing at 50mW output did not see the current drain skyrocket but I recommend that you initially follow this advice so that you don't risk destroying these devices.

Also, be aware that the set's chassis is held into the case by a lug next to the speaker (near the control cut-outs) and by a second lug for the speaker's sub-chassis at the end of the battery compartment. There's also a securing screw.

To remove the chassis, first remove the screw, then slide the metal shield out from under the lug at the battery end. The chassis can then be pulled out end-wise. Conversely, to replace it, slide the chassis in and engage it under the speaker lug, then slide the shield under the lug at the battery end. Above all, be careful and take it slowly.

respectable, with a 40dB signal increase resulting in just a 6dB increase in the audio output. It goes into overload for RF signals at around 80mV/m but that's a pretty strong signal.

The audio frequency response from antenna to loudspeaker is 250Hz to 3.4kHz, which is about what you'd expect. From the volume control to the loudspeaker terminals, it's 280Hz to 180kHz at -3dB, making this yet another set where the high-frequency audio response massively exceeds what's possible overall. It's worth noting that the audio response also shows a rise of around 6dB at 1kHz.

The total harmonic distortion (THD) is about 5.8% at 50mW output, falling to about 5.5% at 10mW. The set begins to clip at 110mW output, at which point the THD is around 7%.

Finally, when the battery voltage is down to 4.5V, there's quite visible crossover distortion in the waveform and the H-618 manages to produce an output of just 18mW before going into clipping. Such low-battery distortion confirms the superiority of diode-biased sets, such as Sony's TR-63 (Silicon Chip, January 2016) and Pye's Jetliner (Silicon Chip, September 2014).

Would I buy another?

So would I buy another H-618 if the opportunity arose? I just might; the red version (model H-619), with a black tuning escutcheon, is a stand-out design. There's a photo of it on Ernst Erb's Radio Museum website: www.radiomuseum.org/r/westinghou_h_619p7_h619_p7_ch_v_2278.html

In the meantime, I'm enjoying the set described here. Its contemporary design is growing on me and it's a pretty good performer.

In fact, it's one of those sets that seems to get passed over a bit too easily. You might consider adding one to your collection.

Different versions

Finally, it's worth noting that the set came in three different-coloured cases and each had a different model number. These model numbers are: 617 (grey), 618 (black) and 619 (red).

Further reading

(1) The only schematic I could find was a less-than-optimal copy on Ernst Erb's site: www.radiomuseum.org/r/westinghou_h_618p7_h618_p7_ch_v_2278.html

(2) Beitman circuit books (from 1938 to 1967-69) are available from: http://makearadio.com/beitmans/

(3) Information on early Westinghouse power transistors is at: www.semiconductormuseum.com/Transistors/LectureHall/JoeKnight/JoeKnight_EarlyPowerTransistorHistory_Westinghouse_Index.htm

(4) There's a link to Riders manuals (big PDFs) at www.makeradio.com (thanks to Dave Schmarder). SC

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Switching bi-amplified speakers

I wonder if you can help me. A friend of mine moved into a house with speakers in various rooms already wired into an RCA panel in the lounge room, enabling her to listen to music throughout the house.

She has a Technics SC-EH590 and the speakers attached directly use two pairs of wires each, one pair marked HF and the other marked LF. The speakers in the other room only have a single pair of terminals each.

The first question is can the speaker HF+ and LF- wires be twisted together as input to a single speaker? I intend using a passive 4-way AV switch as she has speakers in other parts of the house.

The second question is if any of the other speakers are 2-way, can the HF+, RF+ be plugged into the red and white sockets on the switch, and the HF- and LF- be twisted together into the yellow socket on the switch? If you have any recommendations for a more suitable switch, it will be welcome.

Love your magazine. (G. B., Emerald, Vic).

● The Technics SC-EH590 uses bi-amplification, with separate amplifiers for the low-frequency driver and mid/high-frequency drivers in each channel. You can't join the LF and HF outputs together since this would effectively short them out. Unfortunately, this unit is not suitable for driving regular speakers with internal, passive crossovers (ie, just one pair of terminals per speaker).

Your only real option is to use a second power amplifier to drive the speakers in the other room. This could be connected to the "VCR OUT" terminals on the SC-EH590. You could buy or build a small power amplifier and use a load-sensing power board to switch it on simultaneously with the main unit. The separate volume controls could then be used to mute the speakers in the room which is not occupied.

We have described a number of suitable amplifier designs in the magazine. Two you may wish to consider are the Compact 12V 20W Stereo Amplifier (May 2010, Altronics K5136 kit) and the Tiny Tim 10W/Channel Stereo Amplifier (October & December 2013, January 2014).

Making the most of a solar array

My solar panels were supplied with a grid-feed inverter. For the energy fed into the grid, I receive less than a sixth of the rate I am charged at peak or shoulder times, which is when the power is generated. Could it be arranged to supply my power needs then?

Also if I install battery back-up, can I arrange that if there is power available during peak or shoulder times it is used to supply power needs then and the battery is only charged at off-peak times, perhaps halving the costs?

I think some sort of computer controlled equipment would meet my needs; perhaps one of your readers has an idea or maybe a SILICON CHIP project would do it. (J. J., Engadine, NSW).

● Except for expensive battery storage, there is no easy way to really benefit from solar panels, apart from directly using the power they generate (by using your pool pump or aircon, for example) at the time it is available.

Universal preamplifier not working

I have built the Low-Noise Universal Stereo Preamplifier (SILICON CHIP, April 1994) with the 15V power supply as recommended. I built the power supply first and it checked out OK.

I then built the preamp kit and the voltages are OK according to kit instructions but I get no output. I have checked the wiring and it is correct. I have also checked the voltages on the ICs and they are correct. I have also checked the voltages on the ICs and they are correct.

How A CDI Module Works

I write in the hope that you can explain the operation of a little module used in mowers and small motors. It is quite small, about the area of a postage stamp and 5mm thick – fully encapsulated.

I first came across it many years ago when I was the owner/operator of a Stihl chainsaw. The contact breakers needed to be replaced and when I asked my usual parts/repair man he advised me to install this module in place of the contact breakers.

I took a bit of persuading but he was quite adamant, so I tried it, very successfully. Some years later when the chainsaw suffered a catastrophic failure I used this same module to replace the contact breakers in a Victa lawn mower with great success. Both engines are 2-stroke. I recall that there was a range of modules to suit different engines.

I was told by my usual dealer that they are no longer available and I need one to repair a later model Victa 2-stroke lawn mower which appears to have had one fitted as new.

The most puzzling aspect to me is: how does it know when to initiate the spark? When there was a contact breaker, there would be a specification such as contacts should open when the piston is 1/8-inch before top dead centre, or similar. Thanks for any help. (M. S., Narrogin, WA).

● We described the principle of operation of these CDI (capacitor discharge ignition) modules in an article in the May 2008 issue (www.siliconchip.com.au/Issue/2008/May/Replacement+CDI+Module+For+Small+Petrol+Motors). This article also described a replacement module design which you can build quite easily, using a PCB from our website or a kit from Jaycar, Cat KC5466; www.jaycar.com.au/p/KC546

Induction Motor Speed Controller Query

I must say I am very impressed with the Induction Motor Speed Controller kit I purchased from Altronics in Perth. Its assembly, start-up, and operation are excellent. Your comments in the text are correct; it is a very quiet motor controller.

I've read the section on the sinusoidal wave generation code a few times. But I cannot say I get the full maths behind this. Is there any chance that you would pass on the calculation in a little more detail, so I can see more on how you did this?

It describes the output as variable voltage-variable frequency. Variable frequency I understand. As for variable voltage, I don't quite see how this works, unless it's just that the smaller current develops the smaller voltage in the windings.

I'm looking to use this kit as the basis for a controller that specifically controls motor torque. I want to be able to dial up a certain torque level. RPM is secondary in the application.

I would like to use the kit as the prototype and lower the main bus voltage down from 320V to 60V DC so I can safely perform measurements until the design is beginning to work. I would say I'm going to have to play with the values of the resistors to set up IC2 correctly, and make it so it does not shut down the SD/OD input to IC1.

Did you get this design from ideas from a particular motor design text? If so, can you recommend a good one that will help me out? Any comments/tips much appreciated. Keep up the great work; love the magazine. (C. R., Karrinyup, WA).

● Infineon application note AP-16097 "Different PWM Waveforms Generation for 3-Phase AC Induction Motors . . ." explains in detail how 3-phase sinewaves are generated via PWM to drive an induction motor. It can be downloaded from: www.infineon.com/dgdl/AP1609710_different_PWM_for_three_phase_ACIM.pdf?fileId=db3a304412b407950112b40a1bf20453

The lower voltage is produced by varying the PWM waveform so that the pulses are shorter throughout the generated sinewave compared to the full peak-to-peak sinewave pulse widths. The inductance of the motor windings effectively filters the PWM square-wave to give a smoother voltage which is proportional to the pulse width.

The original designer of this project, Andrew Levido, produced the design based on years of experience building and working on this type of controller.

structions. When I connect it to a line input on my amplifier, I get a loud hum and an extremely faint signal. I am certain the voltage being fed in is of the correct polarity.

Power is from an old tape deck that I gutted to use for the case and 240VAC transformer. It puts out 22V which I feed into the 15V power supply. I have checked component layout for the RIAA circuit and it is OK. I have used correct values for resistors and capacitors and left out the ones not mentioned, with no link in the place of the omitted components.

Any suggestion or advice would be appreciated as this is my first project build and I was looking to go on to the 135W power amplifier. (R. H., via email).

● Make sure you are supplying the circuit with both +15V and -15V. Also check that all components are correctly placed. Be sure to include the two wire links for pins 3 and 5 of IC1.

Universal regulator component failures

I have just recently built the delightfully compact and useful Universal Regulator Mk2 (Silicon Chip, May 2015) but I am struggling with a small problem. I have fitted all the components to the PCB as in Fig.5 and am using a 17VAC plugpack to power it.

I managed to get +15V and -15V at CON2 as expected and 5V at CON3 but found to my surprise that REG4 had failed. But my main concern which I can not get my head around is that after about half a minute, my LED popped and went out. I removed it and measured across the two mounting holes and obtained 30V.

I measured the 3kΩ resistor and that was good and checked and re-checked for any shortcomings in my soldering etc but found nothing anywhere; in fact it is very neat soldering if I do say so myself. So where to from here?

I don't see how a LED can survive very long with an applied 30V DC. Should I have omitted D2 and D4 as you suggested? Would that make any appreciable difference? Or any other suggestions that might assist? (B. T., via email).

● If REG4 failed, that suggests a problem (possibly bad solder joint) with REG3. If its ground connection goes open circuit, REG4's input would be driven to much too high a voltage and this could cause REG4 to fail. We can't think of what else would, other than a failure in REG3 or an accidental short circuit due to some kind of metal object contacting the board.

The 3kΩ series resistor would limit the LED current to no more than 10mA. At this current level, there should be about 2.2V across the LED. That should not damage it. We suspect either a faulty LED or some kind of accidental short circuit across the 3kΩ resistor, exposing the LED to the full supply voltage.

With the LED removed, you would get 30V across its pads but that's because there is no current flowing through that part of the circuit. That won't tell you anything about the conditions that would exist with the LED in circuit.

Omitting D2 and D4 won't make any difference to circuit operation. Check the board carefully and make sure nothing can accidentally short. It should be robust as designed.

Wideband oxygen controller display kit

I just bought a Wideband Oxygen Controller kit from Jaycar (KC5486), based on an article in the September 2009 issue. It says it requires a Wideband Display Kit (KC5485) based on the October 2009 design. Is it still possible to get this?

● The original project is now obsolete but we produced a revised version in the June, July & August 2012 issues. You can see a 2-page preview of the first article at www.siliconchip.com.au/

Issue/2012/June/Wideband+Oxygen+Sensor+Controller+Mk.2%2C+Pt.1

We can sell the relevant issues from our website shop and we can also supply the two PCBs and programmed micro for the project at www.siliconchip.com.au/Shop/?article=640

Neck loop coupler queries

I saw a schematic for the Microphone to Neck Loop Coupler (SILICON CHIP, March 2011) on your website and I'm a little confused with three things:
(1) What diode is ZD1?
(2) In the image I see capacitors that don't look like ceramic disk capacitors but another kind. What kind are they and does it matter which kind I use?
(3) Pins 1 & 8 of the LM386 look to be free, so I'm assuming they're not connected to anything. Is that correct? (G. G., via email).

- ZD1 is a 4.7V zener diode which forms part of the battery indicator. It reduces the voltage so that the LED can shine brightly when the battery is 9V but very dim when the battery is below 7.2V.

Most of the capacitors are electrolytic types but you may be referring to the MKT (metallised polyester) capacitors. It does matter which type you use to some extent, since MKT capacitors tend to be more linear than ceramic. The circuit would still work with ceramic capacitors substituted but the sound quality may be reduced.

As you state, pins 1 & 8 of the LM386 are left open (unconnected). The complete article contains more details on the circuit and is available for online viewing or via purchasing a back issue at the following link: www.siliconchip.com.au/Issue/2011/March/Microphone+To+Neck+Loop+Coupler+For+Hearing+Aids

Replacement wheelchair controller

I would like to use one of your controllers to replace the speed controller on a 24V wheelchair for which parts are no longer a viable option.

Is there any simple way to sync two controller boards together so that when the operator goes forwards or backwards, the motor speeds are the same and the chair does not go around in big circles and the user does not have to make continuous corrections?

Your Motor Speed Controller (SILICON CHIP, June 2011) is really great and I have used it in a number of projects, including a video camera dolly, a trailer tug, a gate opener, a lawnmower pusher (for a hilly section) and a dog walker. These use old wheelchair motors, gearbox drives and wheels, which you can get for about $25. (K. H., NZ).

- The control potentiometers for direction on the wheelchair should be closely matched so the two motors drive at a similar speed. You could

Reducing Phono Preamplifier Gain

I've built the Magnetic Cartridge Preamplifier project from the August 2006 issue of SILICON CHIP. It works OK but can you suggest a way to reduce the minimum gain on the volume pot so that it is quieter on minimum volume?

I don't mind if doing this reduces the maximum volume. I'm running directly to line-in on a 125W amplifier to drive power-hungry speakers and sometimes it's just a bit loud. (R. H., via email).

- You can reduce the minimum gain by increasing the value of both 1kΩ resistors between pins 2 & 6 of IC1a & IC1b. The 47µF non-polarised capacitor connected in series with each resistor will need to be reduced by a similar amount. So for example, if you say make the 1kΩ resistors 4.7kΩ, the capacitors should be 10µF (non-polarised).

This would reduce the volume at both ends of the adjustment range by a little more than 12dB. Using 2.2kΩ resistors and 22µF non-polarised capacitors will reduce the level by a smaller but still noticeable amount of just over 6dB.

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PIC-TOC Automatic Dimming

I have always been fascinated with clocks and have constructed many of the designs you have published over the past years. Recently, while thumbing through the current Altronics catalog, I came across the "PIC-TOC Simple Digital Alarm Clock" by Michael Moore (SILICON CHIP, July 2001).

Naturally, I had to purchase the kit and construct the clock. So far good so good; everything works fine but I have just one question. At 8pm the display changes to about half-brilliance and resumes full brilliance at 7am. Is this part and parcel of the PIC software or do I have a problem? (K. J., via email).

● We had a look at the software and it does include display dimming from between 8pm and 7am. The extract of the software that determines this is shown below. This sets a flag high between these two times but is clear afterwards. The display multiplexing duty cycle is reduced to achieve dimming.

```
movf hr24,w ;- IS IT TIME TO DIM? -
sublw 0x06 ; <= *** last hour to dim (in hexadecimal)***
bcf dcounter_flag,4 ; the flag is cleared but set as per below
btfsc status,c ; c is set if 6 - hr24 >= 0
bsf dcounter_flag,4; so before 7am the flag is set high

movlw 0x14 ; <= *** first hour to dim (in hexadecimal)***
subwf hr24,w ;
btfsc status,c ; c is set if hr24 - 20 >= 0
bsf dcounter_flag,4; so after 8pm the flag is set high
```

add a trimming resistance across the higher resistance pot should they not be matched for the straight-ahead direction.

The only way to fully sync the two controllers would be to drive the output Mosfets from one controller, ie, each Mosfet is driven via its own 47Ω resistor that connects to the emitter of Q3. For turning the wheelchair, the motors would need to be driven independently. So then you would want the second controller to be again driven by its own output.

You could incorporate a relay to switch the Mosfet drive signals so both are driven in sync for straight-ahead but independently when turning.

Loudspeaker switching

I have a requirement to switch one set of speakers between two audio amplifiers. One of the amplifiers is the CLASSiC D and I am therefore looking at a power handling requirement which exceeds simple rotary switches. The other amplifier is driven by my Sony television.

The sources have adequate volume and controls, so no additional control is required. I simply want to be able to connect my Wharfedale speakers to one or the other program source. The commercial devices I can find seem to work the other way, ie, one amplifier to two sets of speakers.

Given the power requirements my thinking is to construct a switching mechanism using relays which would ensure isolation between the amplifiers and easily handle the power. Do you think this is a good approach to the problem or do you have any other suggestions? (B. D., Hope Valley, SA).

● As you have noted, there are plenty of devices which will switch two pairs of loudspeakers to one amplifier. In theory, such a device should do exactly what you require, ie, switching one set of speakers between two amplifiers by using the unit in reverse.

However, this is only feasible provided the respective outputs are isolated from each other, ie, no common lines between them.

Valve preamplifier capacitor query

Is a rating of 50V DC sufficient for the 150pF and 100pF capacitors in the valve preamp (SILICON CHIP, January & February 2016)? Can you suggest a retailer and part numbers so I can order some of these? (J. B. P., via email).

● 50V DC is fine for those capacitors. The 150pF capacitor is used as a timing capacitor for REG2 which has an ~12V supply. The 100pF capacitors filter the incoming audio signals so will only be exposed to a few volts peak under normal conditions.

Most electronics retailers will have suitable parts, including Jaycar and Altronics. While not critical, it's best to use NP0 ("Negative positive zero" – zero temperature coefficient) types for the 100pF units; we believe Jaycar and Altronics supply NP0 for values up to 100pF. If the 150pF is NP0 too that would ensure the power supply operating frequency is accurate and stable but it should work with just about any ceramic capacitor.

The Jaycar part numbers are RC5324 and RC5326. Altronics part numbers are R2822 and R2824.

Car LED lamp replacement confusion

I am mystified as to why we have to place a load resistor in a car's blinker circuit when replacing the 21W blinker globes with low current LEDs, reducing the loading on the car's alternator.

Surely there must be a way to place LED blinker globes and replace the existing blinker relay with another one that flashes at the same rate with the LEDs in place. A "LED-friendly" flasher unit must be able to be made simply and cheaply.

I understand that modern cars do monitor some light bulb circuits such as the brake bulbs but I don't know about blinker bulb checking, apart from the rate changing when one globe fails. Could a LED-friendly flasher circuit be investigated? Thank you for a great magazine. (M. S., via email).

● We would not be worried about the loading of the flasher bulbs on the alternator of a modern car, especially as the flashers are only used intermittently. Compared to the load of the headlights, the flasher circuit is trivial.

We have found that many so-called LED equivalents to 12V automotive lamps are simply not bright enough or their overall light distribution does not work well; fitting them would be a backward step. Nor can you use white-LED equivalents in many cars because the lamp housings have clear lenses and therefore need amber tinted lamps (or amber/orange LEDs).

Third, we simply do not know about

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Ask SILICON CHIP

. . . continued from page 94

all the different lamp monitoring arrangements used in modern cars. Some cars do not monitor the flasher lamps at all but the blinker unit will flash more rapidly, as you noted.

Finally, it turns out that there are relay/LED driver modules available from Jaycar. There are two models: the "CFL-13 JL-02" www.jaycar.com.au/p/SY4018 and the "CFL-14 JL-02" www.jaycar.com.au/p/SY4016

LED GPS Clock 1pps query

Having read the two parts of the High-Visibility 6-Digit LED GPS Clock in the January & February 2016 issues, I'm wondering if it's possible to leave out the GPS module and feed in a 1PPS signal from an existing external source. Also, would it be possible to program the remote or provide an extra switch to swap between two time zones?

The purpose would be to have local time and UTC time from a single accurate clock. Though I'm guessing it would also be fun to have two separate clocks, perhaps with different colours! Many thanks for the great construction articles. (A. W., via email).

● If pulses are received on the 1PPS pin, they are assumed to be valid 1Hz pulses, regardless of whether the unit has had any serial communication

Notes & Errata

Universal Speaker protector Mk3 (November 2015): the SMD bridge rectifier pads on the published (RevB) PCB are not wired correctly. The negative terminal goes go GND rather than LK1. As a result, if LK1 is left out but the SMD bridge rectifier is fitted, it will burn out or a track will fuse. In this case, cut the track to the bridge rectifier's negative pad (coming from the left side). This is fixed with the RevC PCB, which will be supplied once the stock of RevB boards is exhausted.

High Visibility 6-Digit LED GPS Clock, December 2015 & January 2016: the circuit diagram (Fig.1) on page 39 of the December 2015 issue shows R8 and R9 swapped. They are correct on the overlay diagram (Fig.2) on page 42.

Ask Silicon Chip

. . . continued from page 95

with a GPS receiver. You would have to try it but applying 1Hz pulses to the 1PPS input should keep the time locked to that source. You would need to set the initial time manually.

The latest firmware (RevD) adds a function whereby a button on the remote can switch the application of the current time zone on and off, switching the display between it and UTC/GMT. If you build two clocks, you could wire the GPS pins up in parallel and use a single module. The clocks should then stay perfectly synchronised. You would need to set them up using different sets of IR remote control codes.

Programming the LCD BackPack

I have ordered the kit for the LCD BackPack from the February 2016 issue. I am new to Micromite programming, although I have been using the Proton Basic interface for quite a few years, so BASIC is fairly simple for me. The only question that I have is how to link to the Micromite panel to upload the program. Do I need to build the ASCII Video Terminal, as described in the July 2014 issue, to do this? (M. F., Wyongah, NSW).

- You could use the ASCII Video Terminal to program the Micromite LCD BackPack but you don't have to. You can use any computer with a serial interface.

Most people would use a USB-to-serial adaptor to program the Micromite. This was mentioned/explained in previous Micromite articles, eg, on page 33 of the May 2014 issue. It was also explained in some detail on pages 24 & 25 of the February 2016 issue.

There are plenty of places to get USB serial interfaces, eg, Jaycar XC4464 and Altronics Z6225. SC

Next Issue

The May 2016 issue of Silicon Chip is due on sale in newsagents by Thursday 28th April. Expect postal delivery of subscription copies in Australia between April 28th and May 6th.

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